RECORDS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

VOL. XVI.

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AFGHANISTAN
BELOOCHISTAN
IRAN OR PERSIA
HERAT
PESHAWUR
CANDAHAR
KHELAT
ARABIAN SEA
Gulf of Cutch
Gulf of Cambay
BOMBAY
Cape Monze
Hyderabad
Ahmedabad
BURAWUL POOR
Dadur
Bella
Sarawan

RECORDS

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GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1883. [February.

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1882.

South Rewah: Umaria coal field.

Mr. Hughes.

The most important result of the past season's work has been the proving of the new coal field of Umaria at the west end of the South Rewah Gondwána basin, within 34 miles of Katni Station on the East Indian Railway. This field was mentioned in the last annual report, and Mr. Hughes had given a notice of it, in the Records for 1881 (Vol. XIV, pt. 4). The actual area of exposed coal measures is small (about 5 square miles), in an angle between the gneissic rocks and the great spread of newer Gondwána sandstone to the north-east. The outcrop of coal had been known for many years, but its appearance at the surface was not promising. All this area had been surveyed in 1872 by Mr. Hacket, without distinguishing the true coal measures; but, from what I had seen of the ground (in March 1869), on a preliminary inspection between Raniganj and Jabalpur, I was aware that further examination would be necessary before anything could be published. Mr. Hughes' success was then no chance find; he recognised a difference between the Umaria sandstone and that of the adjoining area, and he had close search made for fossils, from the evidence of which there was no longer any doubt of those rocks being on the horizon of the regular coal measures. He then at once marked sites for trial borings; and these were carried out with very commendable expedition by the local authorities. The results as to the extent, thickness, and quality of the coal are very promising. A notice of these borings was given by Mr. Hughes in the Records for August last. Railway surveys are now being made for a line from Katni to the coal field.

The field thus opened to enterprise is very extensive. Umaria is the nearest possible source of coal for the North-Western Provinces; and immediately east of it lies the immense coal field of Sohágpur, which district is also rich in

agricultural produce and the natural entrepôt for the surrounding forest tracts. From Sohágpur southwards lies the least difficult line of communication between northern and southern India, into the plains of Chhattisgarh, leading down the Máhánadi valley to Cuttack, and up it over the plateau of Bastar to Vizagapatam.

Not the least important result of this new opening is the opportunity it gives for successful iron manufacture. I know of no spot in India where there is such an abundant supply of a variety of first class iron ores as in the neighbourhood of Katni. Much of the lime now used in Calcutta comes from Katni, and other requisites will probably be forthcoming, if the coal fulfils our expectations.

Mr. Hughes extended his survey of the Sohágpur coal field eastwards into Sirgujah. He reports in very encouraging terms of the services rendered by Sub-Assistant Hira Lal.

SHAHPUR COAL BORINGS.

In the annual report for 1877 (Rec. XI, p. 7) a notice was given of the explorations for coal in the Sátpura region carried on by the Central Provinces Government under my advice; and the concluding operations of those trials are given at page 97 of the Records for 1879 (Vol. XII). Most of those trials were near the northern edge of the basin close to the Narbada valley, and four of them were in interior valleys. In every case the object was to find the coal measures themselves, for the borings all started in rocks known to be of later formation, and in one case only, that close to Mohpáni, was there an outcrop of the coal measures anywhere near. None of them were successful; and it was then pointed out that the nearest ground where there was a direct prospect of coal was in the Shahpur field on the south side of the basin. The coal outcrops there had been reported on separately by three officers of the Survey (in 1859, 1866, and 1875), but none held out any promise of valuable seams. The latest of these surveys was by me (published with a map in Vol. VIII of the Records), and I then marked three sites for borings in different parts of the field, in view of future experimental exploration. These trials were taken up in February 1881, by the Public Works Department of the Central Provinces, and the last of them was closed on the 11th of October 1882 under my instructions. Two of them were made to a depth of 400 feet, and the third to 539 feet. They all passed through several coaly seams, with some thin bands of coal; but none were of sufficient promise to recommend the sinking of a trial shaft. I believe that all the coal-bearing measures were passed through in each boring, but the seams are even poorer than at their outcrops. The coal prospects in the Sátpura basin are thus for the present reduced (besides the Mohpáni mines) to the Pench valley field, of which Mr. Blanford gave a very encouraging report in 1866 (Records, Vol. XV, pt. 2, 1882). This field has naturally been left to the last on account of its comparative inaccessibility; but the engineering difficulties to be overcome are nothing like so great as those on the new Indore and Bhopal State Railways, and a line from Itarsi up the Tawa valley to the Pench would be in every respect the most favourable for crossing the Sátpura range between the Nárbada valley and Nágpur. Such a line would pass along the Shahpur coal field, and might lead to a further exploration of those measures.

ASSAM : DARANGGIRI COAL FIELD. *Mr. LaTouche.*

The cretaceous coal field of Daranggiri in the Gáro hills, reported on by Mr. LaTouche (Records, Vol. XV, pt. 3) during last season, proved quite as good as was expected; the quantity is very considerable and the quality very serviceable; but if the ompany now engaged in opening out the coal fields of Upper Assam achieves nything like the service it proposes, it would scarcely pay to work the much iferior coal of Daranggiri. Mr. LaTouche is now engaged in tracing the coal of he Jaintia hills eastwards, with reference to a project for a railway through forth Cachar.

SOUTHERN INDIA. *Mr. Foote.*

Mr. Foote was engaged in the districts of Mádura and Tinnevelly, principally in completing his map of the coastal region, and joining this work with that of Mr. King in Travancore. The principal features of the ground had been examined in revious seasons, so there is nothing particular to be noticed. A detailed account f this large area will be published during the current year. Late in the season Mr. Foote made a traverse across part of the Mysore gold fields, an account of which is published in the Records for November.

BILLA-SURGAM CAVES.

An object of much interest has long been awaiting investigation in the Madras Presidency, in the osseous cave-deposits of the Karnúl district. This interest is more than geological; at least, or a large section of the intelligent public early pre-historic man is their only ink with geological studies. India has been a focus of great expectation in this natter, upon the assumed evolutional principle that the natural conditions in ropical or sub-tropical regions were most favourable for organic development, and ecause the earliest known civilisations had arisen in such regions. Nine years go, in 1873, there was a momentary confirmation of those hopes, when an undoubtedly manufactured stone implement was found by Mr. Hacket in the beds of he Narbada valley containing remains of extinct varieties of mammals, deposits which had been considered by Falkoner and Dr. Oldham on palæontological grounds s of pliocene age. This 'find' (the word 'discovery' might well be reserved for he fruits of mental effort) gave fresh interest to the question of age of the Narbada osseous gravels, and from a purely geological (stratigraphical) discussion I gave reasons (Records, Vol. VI, pt. 3) showing that they are probably of late post-tertiary time—a view that has since been adopted. At the same time I ventured to impugn the *á priori* doctrine as to the birth-place of mankind, suggesting that, although the remains of the most man-like monkey might be found in tropical regions, we might rather expect to find traces of the most monkey-like man where now the least monkey-like men are found to flourish, taking mind as the characteristic. The early civilised peoples of tropical countries were probably not indigenous.

The cave-test has still to be applied. Some of the most interesting early human remains have been found in cave-deposits; and under the inspiration of the doctrine aforesaid, a party was got up a couple of years ago at private expense to explore caves in Borneo; but the success has not fulfilled the expectations. Apart the human question altogether (the special urgency of which is now rather popular than scientific), great biological interest attaches to any rich deposit of

mammalian remains, and I am strongly urged to take some steps to have the Karnúl caves explored, for there can be no doubt of the information regarding them as announced by the distinguished pioneer of geology in Southern India, Captain Newbold, F.R.S. I have never failed to appreciate the importance of this matter, though I am aware of an impression abroad that I disregard palæontological interests, for which supposition there can be no better foundation than that I have never cared to dabble in matters that can only be profitably handled by experts. In October 1876, within six months of my taking charge of the Survey, I made official inquiries regarding the Billa-Surgam caves, as no notice was made of their whereabouts in the memoir and map descriptive of the Kadapa and Karnúl basin by Messrs. King and Foote. I intended that Mr. Lydekker should visit the caves and report with a view to further exploration. The Madras famine supervened, and no later opportunity offered without too great a sacrifice of current work.

Mr. Blanford makes conspicuous mention of these caves in the Manual of the Geology of India (page 381). Captain Newbold in 1844 described them as situated in latitude 15° 25′, longitude 78° 15′, which should be, as taken from a map of that date (Indian Atlas, Sheet No. 76, of 1842), about 7 miles to north-by-west from Banaganpilli. In the answer I received (dated 10th January 1877) from the Collector of Karnúl, this officer says :—" There is no place near Banaganpilli which goes by the name of Billa-Surgam and noted for any caves containing fossil stones. There is, however, a village called Bilum, 7 miles south-east of Owk in the Koilkuntla taluk, containing some caves, but the Deputy Collector who inspected them says they contain only slate stones." This position would be about 12 miles to south-by-west of Banaganpilli. Both these spots are in the Jamalmadgu limestone, of Messrs. King and Foote's classification, described by Newbold as the 'diamond limestone.'

It is most unlikely that an error of 18 miles would occur in his description of the position, but the coincidence of the similar name and the caves gives a strong presumption that Bilum is Newbold's locality, and that there is a printer's error in the statement of the latitude. He describes the mouths of the caves as from 46 to 60 feet high, falling rapidly to passages which it is necessary to traverse on hands and knees. This obscurity as to the occurrence of the caves offers some explanation of the omission of any mention of them in the published description of that ground; but I would notice the circumstance as an illustration of the condition of our work in India, the imperative object being to furnish in the first instance and as soon as possible a good general sketch of the geology of India. Had our geologists taken in 'cave-hunting' and the like, the map and manual published in 1879 might have appeared about the year 3000. There is, however, no failure of apprehension as to the supreme importance to advanced science of more detailed researches, and I hope to find an early opportunity for the exploration of the Billa-Surgam caves.

KHANDESH; CRETACEOUS: *Mr. Bose.*

Mr. Bose's second season's work in this ground has not added much to the fossil evidence upon which he indicated a correlation of the upper beds with the threefold division of the cretaceous rocks of Southern India, relegating the underlying Nimár

sandstone to a lower cretaceous horizon, as mentioned in last year's annual report; nor is there any fresh observation to disturb that suggested arrangement. He gives some interesting facts showing the association of the Lameta beds with agglomerates of the trappean period; and his microscopic examination of the traps themselves has thrown new light upon the constitution of some of their subordinate varieties. When Mr. Bose was sent to that ground, it was hoped (without authority) that the new maps containing the north-western and south-western extensions of the cretaceous deposits in the Rewa-Kánta country would be available, so that the geological region might be described in one memoir. As there is even now no near prospect of those topographical maps being completed, Mr. Bose's work will be published up to date.

RAJPUTANA; *Mr. Hacket.*

In extension of his previous survey, Mr. Hacket took up work in the wilder parts of the Arvali range in southern Meywar, but in the end of January he was warned by the Political Agent that it would not be safe for him to continue in that part of the country on account of the unquiet state of the Bhils. Mr. Hacket employed the rest of the season very usefully in examining some intricate features along the Vindyan boundary to the north-east of Neemuch.

Sub-Assistant Kishen Singh has mapped a large area of the plateau of Málwa trap and Vindhyans about and north of Goona. The boundaries are, I believe, sufficiently approximate for those formations, and for present purposes; but little or no information is given regarding the rock features upon which a description of the area could be given.

KATTYWAR; *Mr. Fedden.*

Mr. Fedden surveyed a large area along the coastal region, from Bhávnagar to Madhapur, mostly of trap and post-tertiary rocks, with a remnant of tertiary beds on the western sea-margin. A few fossils were obtained from these at Piram (Perim) Island. The ossiferous conglomerates of this well-known locality are the highest beds of the section; but Mr. Fedden considers them to be closely associated with the deposits containing marine shells forming the adjoining coast, which he correlates with the Gáj horizon (of Sind). At Gogha, a little north of Piram, a boring was once made in these strata to a depth of 355 feet, stiff blue clay being the prevailing rock in the lower portion.

THE NORTH-WEST FRONTIER; *Mr. Blanford.*

The principal object of Mr. Blanford's work in the field season 1881-82 was to endeavour to trace northward the well-marked series of tertiary rocks found in Sind, and to follow the continuation of them, if possible, into the Punjab, where there is not the same clue to classification in the presence of marine beds above the eocene.

Before taking up this work, Mr. Blanford was called upon to report again upon the coal deposits to the west of Sibi; so he marched by the Bolán pass to Quetta, examining the coal seams of Mach on the road. From Quetta to Sibi he returned by the Harnai route, and visited the Sharag (or Sharigh) coal locality. From Sibi he skirted the western boundary of the Bhugti Hills, and then marched from Jacobabad to Harrand in the Punjab, through the heart of the Bhugti country. From Harrand he proceeded northward along the eastern flank of the

Sulimán range, to some distance north of Dera Gházi Khán. Here, in the middle of February, a severe attack of fever and liver compelled him to leave the field, and he shortly afterwards returned to Calcutta and was obliged to go to Europe on medical certificate.

A note, containing the results of Mr. Blanford's examination of the coal seams at Mach and Sharag was published in Part 3 of the Records for 1882. He considers the quality of the coal fair, but the quantity is insufficient for commercial purposes. The other results of his season's observations have been, besides making some important alterations in Mr. Griesbach's work about Quetta, to effect a preliminary exploration of the country from Quetta to Dera Gházi Khán, and to show that the post-eocene marine deposits of Sind do not continue north to the Punjab border. One of the unfossiliferous groups, however,—the Upper Nari,—is apparently persistent, and the uppermost system, Siwálik or Manchar, can be sub-divided, so that it is practicable to classify the rocks to a certain extent. It was found that the main chain of the Sulimán is composed of hard whitish sandstones, apparently cretaceous, overlying limestones and limestone-shales, with a few fossils belonging to the same system.

Had the work not been interrupted by illness near Dera Gházi Khán, Mr. Blanford would only have been able to examine the Sulimán range for about 30 miles further north. The whole of the area examined was beyond the British frontier; but, whereas, up to a certain point, a little north of that reached, access was practicable with the aid of the district officers and a small escort, further north the country is inhabited by Afghans, and is consequently inaccessible to Europeans. It may, consequently, be considered that the greater portion of the gap between Sind and the Punjab has been bridged over, so far as is practicable.

Some interesting fossils, mammalian and molluscan, were obtained from Lower Siwalik beds, at localities discovered by Captain Vicary nearly 40 years ago in the Bhugti hills. Mr. Blanford's descriptive memoir, with a map, will be published shortly.

MIDDLE HIMALAYA: *Mr. Griesbach.*

On the termination of his short leave in England Mr. Griesbach obtained permission to visit some places on the Continent, in order to see what process would be best for the reproduction of his views of Himalayan sections; but chiefly that he might examine certain foreign collections of fossils from the Himalaya and other parts of Asia for comparison with his own collection. On both points his trip was very serviceable; the collections made in Armenia by Staatsrath von Abich proved especially interesting, as having close relation to the fossils from certain zones in the Himalayan sections. Owing to some unforeseen official delays Mr. Griesbach was a little late in returning to India, which caused him much discomfort in having to cross the outer ranges of mountains after the rains had set in. With the Bhoteas of the frontier Mr. Griesbach experienced the usual difficulties in making arrangements for transport in the high uninhabited regions where his work principally lies. All his endeavours were in this way frustrated to cross the Mana pass, so he had to cover all the ground he could reach in that direction from the Niti pass, and then move to Nilang, where he had

better success in making excursions northwards. The season was so far advanced that the Tibetan guards had left their stations beyond the passes, so this obstruction was removed, but the cold was intense.

MANIPUR: *Mr. Oldham.*

Mr. Oldham accomplished all that could be expected from his excursion with the Manipur-Burma Boundary Commission, having made a complete traverse of the main range into the great alluvial and tertiary basin of the Ningthi (? Namtonai of older maps) or Chindwin (Kyen-dwen), which seems to be a principal tributary of the Irrawadi. If there is any disappointment in the result, the credit (or discredit) of it must be set down to mistaken imagination, and I must confess to having made that mistake. I had, I may say, hoped that the Aracan Yoma of Mr. Theobald's Pegu Report would expand northwards as it approached the Himalayan massif; and that a deeper rock-section would be exposed, with perhaps a core of crystalline rocks, having their roots, even in outcrop, confluent with those of the great Himalayan elevation. The fact is just the reverse. Here, too, no fossils were found; but the rocks are with great probability identifiable with those 400 miles to the south, even to the serpentinous intrusive masses. Mr. Oldham supplemented his east-west traverse by marching from Manipur northward to Kohima in the Nága Hills, returning by the Assam Valley, and he found that newer tertiary rocks encroach more and more towards the axis of the range; so that it seems as if the older rocks may soon be altogether suppressed in that direction. It thus appears that this range is altogether a secondary one, a mere fender of the great Malayan crystalline axis. I need hardly add that I am more satisfied than if my prognostic had proved correct. Mr. Oldham's report has been ready since July, but there is some delay in procuring a map of the topographical survey of the new ground.

Publications.—Two parts of Volume XIX of the Memoirs were published during the year. The first is a description, with numerous illustrations, of the Cachar earthquake of 1869. The descriptive part was written shortly after the event by the late Dr. Oldham, from observations made by himself on the spot. The discussion of the data was supplied, and the whole edited, by Mr. R. D. Oldham. Part 2 is a descriptive catalogue of the thermal springs of India, and Part 3 (now in the Press) is a descriptive catalogue of Indian earthquakes. These also were compiled by Dr. Oldham; the data have now been revised and illustrative maps prepared by Mr. R. D. Oldham. These publications form a good starting point for seismological observation in India, preparations for which on a small scale are now in hand. Several other memoirs are well advanced towards publication, by Mr. Blanford, on the country between Quetta and Dera-Ghâzi-Khân; by Mr. Foote on a large area between Trichinopoli and Cape Comorin; and by Mr. Oldham on parts of Manipur and the Nága Hills.

Volume XV of the Records for 1882 contains numerous (28) papers of more or less practical importance or of scientific interest.

Five fasciculi of the Palæontologia Indica were brought out during the year:—Part 1, Vol. IV, of the Gondwána Flora by Dr. Feistmantel gives a description of

the fossil-flora of the south Rewah basin. Mr. Lydekker describes the Siwâlik and Narbada Equidæ in Vol. II, part 3 of the Tertiary Vertebrata series. Dr. Waagen's first fasciculus on the Brachiopoda of the Productus-limestone in the Salt-range is but a small instalment of this section of his work; but I have already received 30 plates of the sequel. The Brachiopoda form the most numerous and most intricate portion of this group of fossils, and the exhaustive study Dr. Waagen is giving of them will, I have no doubt, be gratefully acknowledged by all palæontologists. Two fasciculi on the fossil Echinoidea of Sind are contributed by Dr. Martin Duncan and Mr. Percy Sladen, to whom the Survey is greatly indebted for their voluntary assistance in this important branch of palæontological research.

Museum.—Of all field work in progress, the corresponding collections of specimens have been kept up to date. A full descriptive catalogue of the systematic series of minerals by Mr. Mallet is nearly through the Press.

Library.—The additions to the library were 1,461 volumes or parts of Volumes; 665 by purchase and 796 by donation or exchange. The titles of all these books as received are published regularly in the Quarterly Records. I think I can promise that the catalogue will be in print by the end of the present year. The preparation of it can only be carried on in the intervals of current work.

Mining Records.—One mining plan was received during the year, from the Raniganj Coal Association.

Seismological Observations.—Proposals have been made before now to establish seismometers in certain parts of India that are subject to comparatively frequent earthquakes. A chief difficulty has been, and must continue to be, to find competent and trustworthy observers at the suitable places. A small expenditure for the purpose has now been sanctioned, enough to set up some simple seismometers at a few stations in north-east Bengal and Assam where meteorological stations are already established, through which agency it is hoped some observations may be secured.

Personnel.—Mr. Blanford was obliged to take sick leave to Europe on the 25th of April, and, under medical advice, he has since been compelled to retire from the service, as no longer able to endure the exposure and fatigue required of the field geologist in India. After 27 years of so arduous a life this result is not surprising; he joined his appointment in India on the 1st of October 1855. From the beginning of his service, Mr. Blanford took a leading part in the work of the Survey; his report on the Talchir coal field is the first paper in our Memoirs, which have now extended to 19 volumes, containing numerous contributions from him. Besides his regular geological labours Mr. Blanford has done much work for the zoology of India, on which he is now a leading authority. He was twice deputed on missions out of India,—with the army to Abyssinia, and with the Seistan Boundary Commission to Persia. Of his researches in both countries he published a full account. He was twice (in 1878 and 1879) elected President of the Asiatic Society of Bengal, an honour never previously conferred on an officer of his standing. So long ago as 1874, he was elected (at his first nomination) a Fellow of the Royal Society, which is the highest non-official distinction an

Englishman can receive. In 1876, Dr. Oldham, on retirement, recommended Mr. Blanford to be his successor as Superintendent of the Geological Survey of India; of this he was only deprived by a small matter of seniority, and in recognition of his high claims Government rewarded him with a special personal remuneration above the pay of his appointment. Personally, as well as professionally, Mr. Blanford's departure will be much regretted by his colleagues in the Survey.

Mr. King was absent on furlough for the whole year. Mr. Wynne was obliged to take successive extensions of sick leave, and is still absent. Mr. Hughes obtained six months' leave on urgent private affairs on the 8th June, which has been extended in England for three months. Mr. Hacket left on furlough for two years on the 20th November. Mr. Lydekker was granted six months' leave on urgent private affairs from the 2nd March, and subsequently by the Secretary of State an extension for one year without pay. Privilege leave for various periods was granted: Mr. Mallet 42 days, Dr. Feistmantel 40 days, and Mr. Medlicott 3 months.

H. B. MEDLICOTT,

Superintendent, Geological Survey of India.

CALCUTTA,
The 23rd of January 1883.

List of Societies and other Institutions from which Publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1882.

AMSTERDAM.—Netherlands Colonial Department.
BASEL.—Natural History Society.
BATAVIA.—Batavian Society of Arts and Sciences.
,, Royal Natural History Society, Netherlands.
BELFAST.—Natural History Society.
BERLIN.—German Geological Society.
,, Royal Prussian Academy of Science.
BOLOGNA.—Academy of Sciences.
BOMBAY.—Meteorological Department, Western India.
BOSTON.—American Academy of Arts and Sciences.
,, Society of Natural History.
BRESLAU.—Silesian Society of Natural History.
BRISTOL.—Bristol Museum.
,, ,, Naturalists' Society.
BRUSSELS.—Geological Survey of Belgium.
,, Royal Geographical Society of Belgium.
,, Royal Malacological Society.
,, Royal Natural History Museum of Belgium.
BUDAPEST.—Geological Institute, Hungary.
BUFFALO.—Society of Natural Sciences.
CAEN.—Linnean Society of Normandy.

CALCUTTA.—Agricultural and Horticultural Society.
,, Asiatic Society of Bengal.
,, Marine Survey.
,, Meteorological Department, Government of India.
CAMBRIDGE (MASS.).—Museum of Comparative Zoology.
CASSEL.—Society of Natural History.
CHRISTIANIA.—Editorial Committee, Norwegian North Atlantic Expedition.
,, L'Association Géodésique Internationale Commission de la Norvège.
COPENHAGEN.—Royal Danish Academy.
DRESDEN.—Isis Society.
DUBLIN.—Royal Geological Society of Ireland.
,, Royal Dublin Society.
,, Royal Irish Academy.
EDINBURGH.—Royal Scottish Society of Arts.
,, Royal Society of Edinburgh.
,, Signet Library.
GENEVA.—Physical and Natural History Society.
GLASGOW.—Geological Society.
,, Philosophical Society.
GOTTINGEN.—Royal Society.
HALLE.—Natural History Society.
HARRISBURG.—Geological Survey of Pennsylvania.
LAUSANNE.—Vandois Society of Natural Science.
LIEGE.—Geological Society of Belgium.
LONDON.—Geological Society.
,, Iron and Steel Institute.
,, Linnean Society.
,, Royal Asiatic Society.
,, Royal Geographical Society.
,, Royal Institute of Great Britain.
,, Royal Society.
,, Society of Arts.
,, Zoological Society.
LYONS.—Museum of Natural Science.
MADISON.—Superintendent of Public Property.
MADRID.—Geographical Society.
MANCHESTER.—Geological Society.
MELBOURNE.—Mining Department, Victoria.
,, Royal Society of Victoria.
MILAN.—Italian Society of Natural Science.
,, Royal Institute of Lombardy.
MONTREAL.—Geological Survey of Canada.
MOSCOW.—Imperial Society of Naturalists.
NAGPUR.—Nagpur Museum.

NEUCHATEL.—Society of Natural Sciences.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Connecticut Academy.
" American Journal of Science.
PARIS.—Academy of Sciences.
" Geological Society of France.
" Indo-Chinese Society.
" Mining Department.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
" American Philosophical Society.
" Franklin Institute.
PISA.—Society of Natural Sciences, Tuscany.
ROME.—Royal Geological Commission of Italy.
" Royal Academy.
ROORKEE.—Thomason College of Civil Engineering.
SAINT PETERSBURG.—Imperial Academy of Sciences.
" Imperial Russian Mineralogical Society.
SALEM (MASS.)—American Association for the Advancement of Science.
" Essex Institute.
SHANGHAI.—North China Branch, Royal Asiatic Society.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
SYDNEY.—Australian Museum.
" Department of Mines, New South Wales.
" Royal Society of New South Wales.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Science.
VENICE.—Royal Institute of Science, &c.
VIENNA.—Imperial Academy of Sciences.
" Imperial Geological Institute.
WASHINGTON.—Smithsonian Institute.
" United States Geographical Survey west of the 100th Meridian.
WELLINGTON.—New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
" German Naturalists' Society.

The Governments of Bombay, Madras, North-Western Provinces and Oudh and the Punjab.

Chief Commissioners of Assam, British Burma, Central Provinces, and Coorg.

The Commissioner of Inland Customs.

The Residents at Hyderabad and Mysore.

The Surveyor General of India.

Departments of Finance and Commerce, Revenue and Agriculture, Foreign, Forest, and Home.

On the Genus Richthofenia, Kays, (Anomia Lawrenciana, Koninck,) *by* WILLIAM WAAGEN, PH.D., F.G.S. (*With 2 plates*).

IN one of the later numbers of the "Zeitschrift der Deutschen Geologischen Gesellschaft," M. E. Kayser publishes some notes on the fossils of the carboniferous limestone of Lo-ping in China, collected by Baron Richthofen, which fossils seem to be rather similar in type to those of the Productus-limestone of the Salt-range, the description of which is now in progress. He mentions one fossil in particular, the *Anomia Lawrenciana* of deKoninck, for which he proposes the generic denomination of *Richthofenia*.

M. Kayser regards this fossil as belonging to the Brachiopods, very likely somewhere near *Productus*, and this approximately agrees with what I considered it to be. I expressed this opinion in the last remarks appended to the third part of my "Salt-range Fossils" (p. 328); only I was at that time doubtful whether the fossil might not as well be considered a coral.

While preparing the description of the Brachiopods of the Salt-range Productus-limestone, I was obliged also to examine the *Anomia Lawrenciana* more in detail; and the result of this examination was so remarkable that I think it worth while to give a preliminary notice of this fossil, together with such figures as will be necessary to understand the description.

The fossil consists, as has been described already by deKoninck, of two valves, one larger and one smaller (Pl. II, *f.* 7, 8, 9). The larger valve is of a conical shape, with the apex fastened to some foreign body (Pl. I, *f.* 9). The smaller valve is flat, a little sunk into the larger one. The two valves articulate by a rather short straight hinge-line. This hinge-line, however, does not show in the outer appearance of the conical valve; it is only marked inside it. On both sides of the hinge-line, the smaller valve is cut out in a semi-circle to receive thickened parts of the shell of the larger valve. The outer side of the larger valve is rugose, provided with many concentric wrinkles, and bears a variable number of hollow, depressed, diverging, tortuous tubes, which, on the one hand, resemble the root-like appendages of some rugose corals, and, on the other, can be compared to the hollow spines of some *Producti*. The resemblance to the latter is chiefly striking because of the silky lustre of the shell-substance of which they are composed. On the whole, the shell of the fossil is dull when quite intact, and of a silky lustre when the outmost layer of the shell is worn off. Then also appears a very close punctation, similar to that occurring in the shell of *Productus*, which is barely visible to the naked eye.

The punctures are not all equal; some larger ones are disseminated irregularly between great numbers of smaller ones (Pl. I, *f.* 3). As has been mentioned above, the punctures appear only when the outermost layers of the shell are removed. The punctured part does not lie immediately below the epidermoidal shell-layer, but succeeds a very thin layer, also already exhibiting a silky lustre, which shows a very close vertical striation, and is composed of numerous very fine excavated lines (Pl. II, *f.* 8 *b*). Sometimes this striation is even visible on

the outermost dull layer of the shell. Both these layers, the dull one as well as the striated one, are entirely lost in the greater number of specimens.

On the smaller (flat) valve the hollow tubes, which are so very characteristic of the larger valve, are altogether absent. When the shell-substance of this valve is perfectly preserved, it is strewn over with very numerous small papillæ which project slightly from the surface of the shell (Pl. II *f.* 9).

On its interior side this smaller valve bears a distinct, but not very high, median septum, which extends from near the margin opposite the hinge-line, to nearly the middle of the valve. Here, in most specimens, it is replaced by two parallel ridges, which in other specimens, however, are combined in one broader septum. On both sides of these ridges large, more or less rounded impressions appear, which are very strongly marked, and distinctly indented on the side nearest the hinge-line; on the side opposite to it they are less strongly marked, but seem to be also indented (Pl. I, *f.* 1*c.*; Pl. II, *f.* 2). On the hinge-line itself there are, vertical to it, two short, thick and prominent parallel ridges, not dissimilar to hinge-teeth, which are, however, about equally high through their whole extent. They are not in connection with the median septum, but are separated from it by a smooth space. They do not protrude much above the hinge-line. On the whole, they might possibly be compared to the very developed cardinal process of the smaller valve of *Productus*, but the similarity is, in fact, only a very distant one. On both sides of these ridges not a trace of dental grooves can be observed. Neither the reniform bodies, which are such prominent features in the smaller valve of *Productus*, nor distinct dental grooves exist on the sides of the short ridges on the hinge-line. Near the outer margin of this smaller valve there are thorny processes, more or less numerous, directed towards the interior of the shell, similar to those seen in some *Producti* (Pl. II, *f.* 2).

Far more complicated is the structure of the larger valve. It consists of two different parts; the lower, from the apex of the valve up to about the middle of its height, being composed of very numerous narrow water-chambers, divided off by very thin shelly partitions, and the upper forming a large hollow for the reception of the animal. The partitions in the lower part of the shell are very irregular, exactly like the partitions existing in rugose corals. They are, on the whole, convex below, and concave above; not so, however, for their whole extent, as about in their middle they are bent upwards, forming something like a columella, such as exists in many corals. This formation of a columella is caused by the presence of three vertical septa (Pl. I, *f.* 2, 4, 5), which extend from the apex of the shell, through all the partitions, up to the body chamber. By these septa a vertical triangular space is divided off within the larger valve of this fossil, the base of the triangle being formed by the hinge-line, whilst its apex lies in the middle of the shell, where the three vertical septa, which converge towards this centre from both ends of the hinge-line, unite. The median of the three vertical septa extends from the centre towards the hinge-line, without, however, ever uniting with it. All the space between the vertical septa and the hinge-line is also filled up by shelly partitions.

The animal chamber (Pl. I, *f.* 1) is tolerably large; the bottom of it is, however,

situated at very different levels. The triangular space marked off by the vertical septa is much more shallow than the remainder of the chamber; but the latter also is not even, as from the centre of the shell a rounded crest extends, forming a shallow saddle, to the wall opposite the hinge-line. On each side of this crest is a deep hollow which occupies the whole lateral parts of the body chamber. The whole bottom is covered by irregular tolerably minute grooving.

The three vertical septa project into the body chamber as three high upright plates, which converge towards the centre of the shell and are highest near this centre. Their upper margins are denticulate. They do not unite, but remain somewhat apart from each other. On the other side, between them and the hinge-line, there is an ascending plane, none of the plates thus reaching the hinge-line. Of these plates or septa, the median one is the highest. The two lateral are limited on their inner side by very deep narrow grooves; from the median one, on the contrary, on both sides start some low secondary septa, which show, on the whole, a pinnate arrangement. They disappear again, however, before reaching the grooves mentioned above.

The hinge-line is quite straight, and shows only in the middle a slight rounded sinuation for the reception of the two thick terminating branches of the median septum in the smaller valve. Not a trace of any kind of teeth for articulation with the smaller valve is observable.

The inside of the outer walls of the body chamber is provided at very irregular and unequal distances, with tolerably broad and sharp, but not very prominent vertical septa, some of which begin a short distance below the upper border of the chamber, and disappear before reaching the bottom, whilst others begin lower down and then reach down to the bottom of the chamber. The upper termination of each of them bears a round foramen, which forms the entrance to the hollow tubes which can be observed on the outer side of the shell and have been mentioned above (Pl. I, fig. 2). This foramen, however, does not pierce the wall directly, but the tube descends nearly vertically and appears only in the vicinity of the apex at the outer side of the shell.

All round the upper border of the animal-chamber a thickened margin can be observed, which has some similarity to a pallial impression (Pl. I, figs. 1, 8). Of muscular scars nothing can be observed either on the bottom or on the walls of the chamber.

The substance of the shell is of a very singular structure. It is composed in the larger conical valve of three layers. The outer one is very thin, dull and compact outside, and of a silky lustre inside, provided with the characteristic striation and punctation mentioned above. The median layer, the thickest of all, though very irregular in its thickness, is composed of approximately hemispherical cells, such as can be observed in many rugose corals when the radial septa have been obliterated (Pl. I, figs. 2, 7; Pl. II, figs. 1, 5). These cells are arranged in ascending radial rows, and are interrupted at intervals by perfectly straight, radial, very pointedly conical shelly parts (Pl. II, fig. 4) which require further explanation. They begin on the outer shell-layer with a slightly broader base, and extend, in a more or less ascending direction, towards the inner portions of the shell. They are not round but polygonal. All do not

with their sharply pointed ends reach the innermost shell-layers; indeed, most of them stop about half-way. Nor do all of them originate on the outer shell-layer, for some start from the wall of some cell in the median layer of the shell. They seem to be hollow and to form tubes, which apparently communicate with the larger pores, disseminated between the more minute punctation of the shell as described above; but I am not quite certain on these latter points. The hollow tubes which terminate in root-like processes as mentioned above penetrate this median part of the shell in a nearly vertical direction. The innermost layer of the shell is somewhat thicker than the outer one, but otherwise similar to it. The median and the outer layers of the shell fall off easily, and then internal casts of a strange description, which preserve the inner shell-layer, are produced (Pl. I, fig. 8).

In the flat smaller valve the median shell-layer is absent.

Under the microscope, with a magnifying power of 100 diameters and upwards, the whole shell can be seen to be composed of very thin lamellæ, which disunite for the formation of the cells and join together again in the outer layer of the shell. They are mostly vertical in the inner layer of the shell, bent nearly horizontal but irregularly outward in the median layer, and again vertically upward in the outer one.

Each lamella shows a very distinct striation vertical to its planes, caused apparently by prisms of which it is composed. These prisms are thus placed horizontally in the inner shell-layer from the inside of the shell to the outer, in the median layer vertically, and in the outer layer again horizontally.

Besides this striation fine canals can also be distinctly traced, which originate on the inner side of the shell and pierce the different lamellæ of which the shell is composed, causing thus the fine punctation of the inner shell-layer, similar to that occurring in *Productus*. The canals are, however, not simple, but distinctly and manifoldly ramified, and thus absolutely different from those occurring in *Productus*. They are more similar to the canals which pierce the shell of *Crania*. I do not think that these canals may be the work of boring *Thallophyta*. They seem to exhibit another character than the borings of those organisms. I shall, however, give detailed figures of these canals in my large work on the "Salt-range Fossils."

The fossil is gregarious in its occurrence in nature, and the individuals are often so closely packed together that the root-like appendages of one individual are fastened to the individuals around, but I never found two individuals entirely grown together.

These are the facts I have been able to ascertain relating to the structure of this fossil; it remains now to deduce from them the systematic position the fossil ought to occupy. As I have already formerly indicated, I was from the beginning doubtful whether the fossil ought rather to be considered a coral or a Brachiopod, and the views of palæontologists to whom I showed the specimens were quite equally divided between the two classes. Mons. Barrande, as well as Professor Valérin and Möller, were of opinion that this fossil was rather more related to the corals than to any other class of animals, whilst Professor Zittel and Professor Lindström seemed to be more in favour of the view which

places it among the Brachiopods. The characters exhibited by the fossil are indeed, of such a conflicting nature that it becomes extremely difficult to assign to it any place in the system.

In favour of the view which inclines to consider the fossil as a Brachiopod the microscopic structure of the shell can be adduced above all. Its silky lustre is absolutely identical with that of the shell of *Productus*, though this lustre seems not to be effected in both cases by the same means. In the shell of *Productus* it is caused by obliquely ascending prisms, whilst in *Richthofenia* it depends apparently on the fine lamination of the shell as in *Placuna* or similar genera. Of great importance is the prismatic structure of the single laminæ of which the shell of *Richthofenia* is composed. Such a prismatic structure is, as far as I am aware, chiefly characteristic of molluscs or molluscoids. I certainly have not as yet observed this structure in corals. In *Calceola sandalina*, which seems the most kindred form among the corals, a microscopic section through the larger valve showed beautifully its construction of radial septa, but these septa exhibited all a granular, not a prismatic structure.

The punctation of the shell is also very similar to that of *Productus*, and so are the hollow root-like tubes which penetrate the shell-substance of the larger valve, and adhere to other bodies.

The smaller valve can also, on the whole, be very well compared to the same valve of *Productus*, though it remains doubtful whether the thick parallel ridges on the hinge-line of this valve in *Richthofenia* can at all be compared to a cardinal process, and whether the impressions on the valve can be taken as muscular impressions. Reniform bodies are most certainly absent.

Nevertheless, among all the Brachiopods the *Productidæ* are the only ones to which the genus *Richthofenia* might stand in any relation; other Brachiopods are certainly considerably less related to the present genus than the *Productidæ*.

But, though all the points indicated may be in favour of the Brachiopod nature of the present fossil, yet it cannot be denied that there exist also certain points of resemblance between *Richthofenia* and rugose corals. Any one who looks only for a moment at Pl. I, fig. 2, will be convinced of this similarity. The irregular partitions in the lower part of the larger valve; the columella-like part which is divided off by three vertical septa; these septa themselves, which can very well be compared with the primary and the two lateral septa of a rugose coral; the cellular structure of the shell; the septa-like ridges on the outer wall of the animal chambers which are in connection with the hollow canals which pierce the substance of the shell; and the tortuous tubes themselves into which the canals are prolonged on the outer side of the larger valve: all these characters remind one strongly of a rugose coral. There can be no doubt that on a first inspection, ignoring the silky lustre of the shell, one would far more likely be led to regard this fossil as a coral than as a Brachiopod.

There is, however, yet another character to be pointed out, which is even more conflicting than those hitherto adduced; this is the existence of something like a pallial impression round the upper margin of the larger valve, as figured in Pl. I, figs. 1*b* and 8*a*.

This character, as well as the very peculiar appearance of the partial cast as presented in Pl. I, fig. 8, and the longitudinal section, Pl. II, fig. 5, induced e to take yet another group of fossils into consideration for comparison; and ese are the *Rudista* in a restricted sense, as defined by Stoliczka in his work ı the cretaceous bivalves.

It is a very curious fact that with the *Rudista* the same difficulty prevailed to their classification as with the present fossil. They had been considered L. v. Buch as corals, by d'Orbigny as Brachiopods, and recently they are aced by most men of science in the bivalves.

The points of similarity between *Richthofenia* and the *Rudista*, chiefly *Hip-ırites*, are not very numerous, it is true. It is chiefly the section which ay be compared. If we cut open a specimen of *Richthofenia* from the hinge-ıe to the opposite wall, so as just to touch the median vertical septum (Plate , fig. 5), we get a figure very similar to that which we obtain when we cut rough a *Hippurites* so as to touch the first columellar fold (the hinge-fold and e second columellar fold being left untouched), Plate II, fig. 10. The par-ions presented are very similar in both cases. They are bent up in the middle form a kind of columella, and are separated from the outer walls of the shell a sharp line in both cases. It is due to this latter circumstance in both ses that the outer walls of the shell fall off easily, and that such strange ırtial internal casts are formed.

Another point of similarity consists in the direction of the prisms, of which e substance of the shell is composed. The *Rudista* differ from all the other oups of *Pelecypoda* in having the prisms of their outer shell arranged verti-lly, that is to say, longitudinally to the whole extension of the shell. Just the me is the case in the median shell layer of *Richthofenia*, as has been explain-l above.

A third point of similarity of great importance exists in the pallial impres-ɔn, which is common to *Richthofenia* and the *Rudista*; and, finally, it is not uite certain that the sinuations of the large valve of *Richthofenia* on both les of the hinge-line, which stand in so close a connection to the lateral vertical pta may not be regarded as the beginning of the infoldings of the shell, which e so very characteristic for the *Rudista*.

All these points of similarity between the *Rudista* and *Richthofenia* are im-ırtant, as they are in connection with the most striking characters of both ssils; and it cannot as yet be positively denied that *Richthofenia* might ı a predecessor of the *Rudista*. To say anything positive on this point is at esent impossible. The distance in time between *Richthofenia*, which comes obably from the limits between the carboniferous and permian formations, ıd the *Rudista*, which are for the greater part upper cretaceous, is so enormous, ıd every connecting link is as yet absent, that a very close affinity between ıe palæozoic and the cretaceous forms cannot be expected, and thus it will only possible to prove the connection between the present fossil and the *Rudista*, futher members of such a developmental series should be discovered.

As the case now stands, it will probably be most prudent in accordance with ıe microscopic structure of the shell to consider the fossil as something like a

Brachiopod. As far as my opinion goes, I am convinced that *Richthofenia* is a member of a series, which, branching off somewhere from the rugose corals has reached in *Richthofenia* a Brachiopod-like stage, and is going to terminate its career as a Pelecypod, as one of the *Rudista*. But opinion is nothing in science and proofs are everything. I hope that these lines will give an impulse to the elucidation of the very obscure relations of the fossil which has been the object of this paper.

EXPLANATION OF PLATES.

PLATE I.

RICHTHOFENIA LAWRENCIANA, Kon. sp.

Fig. 1. Silicified specimen from the upper region of the Middle Productus limestone of Musa Kheyl. 1*a*, view of the body chamber straight from above; 1*b*, the same slightly oblique from the front; 1*c*, interior side of the smaller valve of the same specimen: all natural size.

" 2. Natural section through a specimen from the coral beds of the Middle Productus-limestone of Virgal; the section being parallel to the hinge line and just touching the termination of the three vertical septa. The cells in the walls of the animal chamber are not quite correctly represented.

" 3. Portion of the shell surface enlarged 4 to 5 times to show the punctation, in a specimen from the upper region of the Middle Productus limestone of Musa Kheyl.

" 4. Fragmentary specimen from the Middle Productus-limestone of the Chittawán; 4*a*, natural section through the lower part of the animal chamber, showing the section of the three upright blades; 4*b*, artificial section, very oblique, lower down through the partitioned part of the shell, showing the vertical septa and the space that is limited off by them.

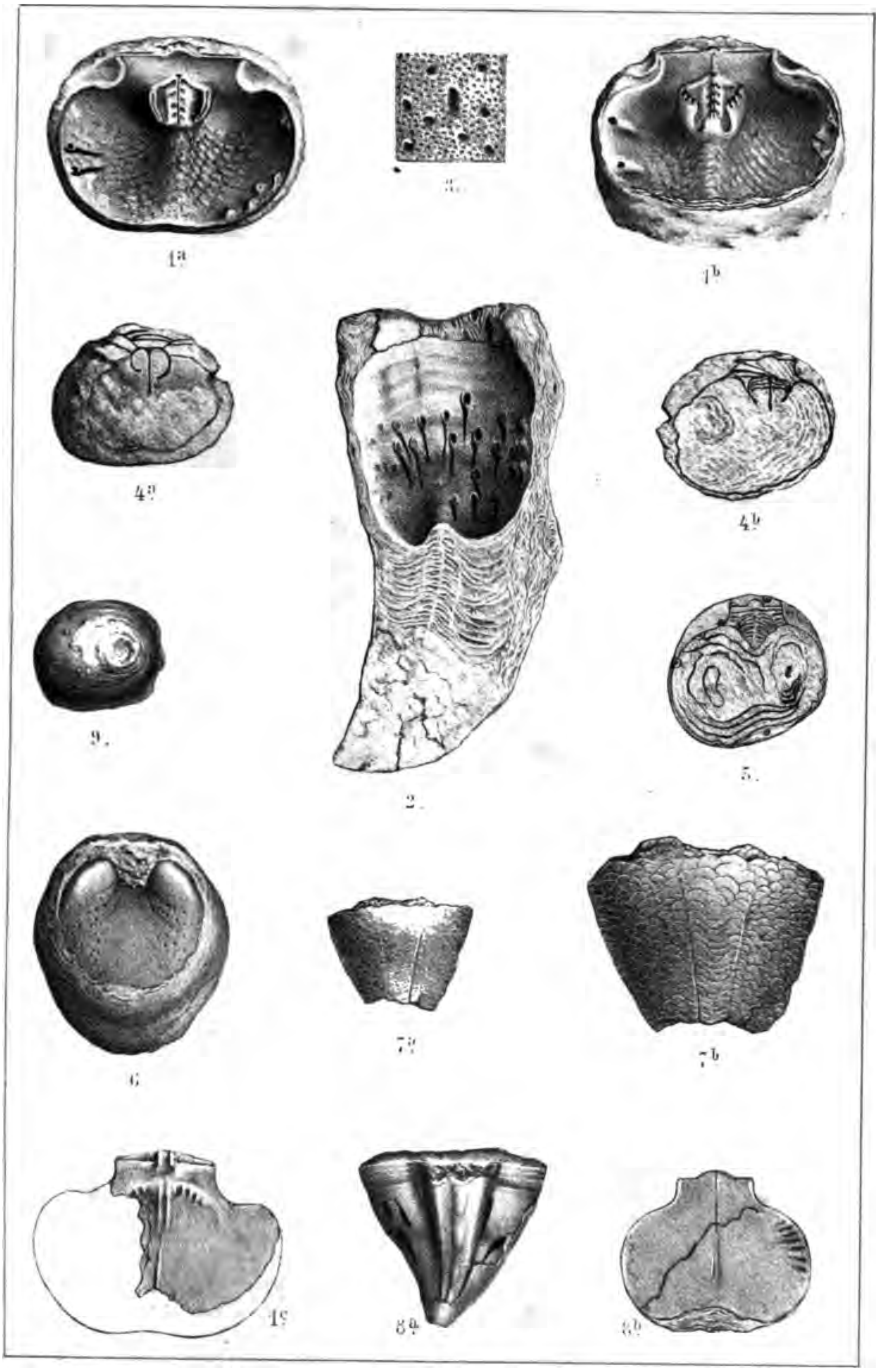
" 5. Artificial transverse section through a specimen from the Lower Productus-limestone of Amb. The two lateral vertical septa unite in the middle.

" 6. One of the partitions of the larger valve seen from below on a broken specimen from the Middle Productus-limestone of the Chittawán.

" 7. Fragmentary specimen, showing the cellular structure of the median shell-layer, the outer layers having been removed by weathering from the Middle Productus-limestone near Khura.

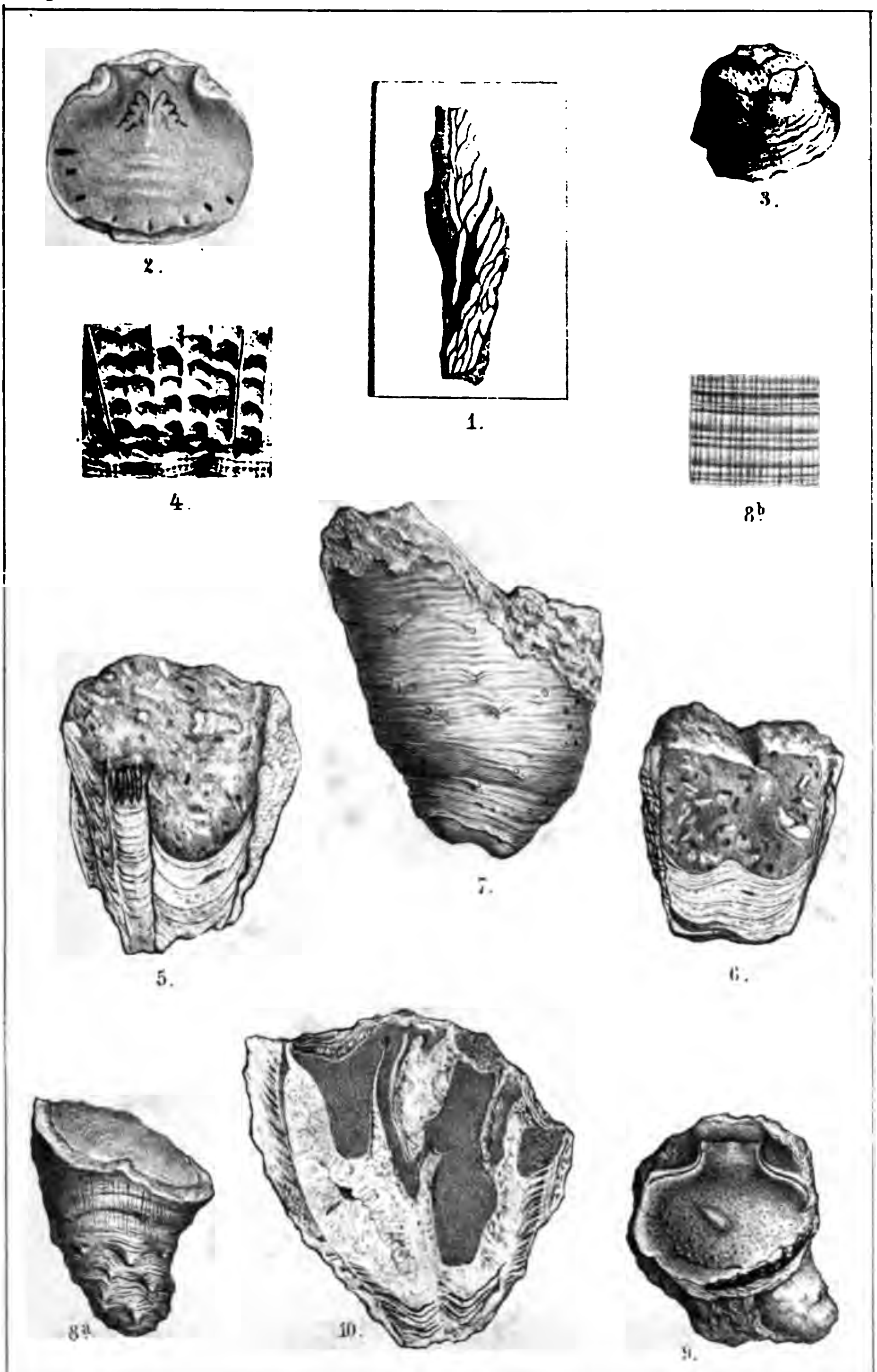
" 8. Partial internal cast of a specimen from Musa Kheyl; *a*, view from the hinge-line; 8*b*, view from the smaller valve.

" 9. Small specimen from the lowest beds of the Middle Productus-limestone of Katta from below, showing the point by which it has been fastened to the bottom of the sea.



A Swoboda del. & lith.

Imp Th. Bannwarth Vienne



A. Swoboda del. & lith.

Imp. Th. Bannwarth Vienne

PLATE II.

Figs. 1—9. RICHTHOFENIA LAWRENCIANA, Kon. sp.

Fig. 10. HIPPURITES, sp.

Fig. 1. Section through the shell of a specimen from the Lower Productus-limestone of Amb enlarged four times. To the right the outer, to the left the inner, side of the shell, at the lower extremity one of the shelly cones which traverse the shell substance; prisms slightly indicated.

„ 2. Internal cast of the smaller valve of a specimen from the Middle Productus-limestone of Musa Kheyl. The spines on the inside of the valve appear as deep grooves.

„ 3. Fragmentary specimen from the Middle Productus-limestone of the Chittawán, viewed from below, to show the irregularity of the partitions, the one figured being made up of five pieces.

„ 4. Fragment of the shell of a specimen from the Upper Productus-limestone (Cephalopoda bed) of Jabi, very obliquely weathered and enlarged about four times, to show the cells and the, in this case exceptionally numerous, shelly cones which are between them.

„ 5. Artificial section through a specimen from the Lower Productus-limestone of Amb. The section is vertical to the hinge-line, just missing the median vertical septum, but yet hitting at the upper end of the columella the secondary septa which are joined to the median one. Mineral matter partly intercalated between the partitions, as in all sections (Pl. I, fig. 2; and Pl. II, fig. 6).

„ 6. Artificial section through a specimen from the Lower Productus-limestone of Amb, the section being parallel to the hinge-line, missing the three vertical septa altogether.

„ 7. External view of a fragmentary but tolerably large specimen from the Middle Productus-limestone of the Chittawán.

„ 8. Specimen with exceptionally well preserved external surface of the larger valve, showing the longitudinal striation from the Lower Productus-limestone of Amb. 8*a*, lateral view, obliquely to the hinge-line; 8*b*, portion of the surface enlarged.

„ 9. Specimen from the Lower Productus-limestone of Amb; view from above to show the smaller valve and the fine granulations by which this as well as the bent over parts of the larger valve is covered.

„ 10. Section through *Hippurites* sp. from the Gosau formation of the Neue Welt near Vienna, figured for comparison with fig. 5. (Property of the K. K. Geologische Reichsanstalt in Vienna.)

On the Geology of South Travancore, *by* R. BRUCE FOOTE, F.G.S., *Deputy Superintendent, Geological Survey of India.* (*With a plate and a map.*)

My colleague, Dr. King, was from various causes obliged to leave the survey of South Travancore, from Trevandrum to Cape Comorin, very unfinished, and it devolved upon me to close up the gap left, so as to join the general survey of this State with the work I had done in Tinnevelly district. The small map which accompanies this paper shows the tract omitted in Dr. King's map, appended to his two papers relating to Travancore, published last year (1882)[1]. The notes I have to offer refer mainly to the tract lying between the coast and the high road leading from Trevandrum into Tinnevelly district through the Arambuli (Aramunny) pass.

The topographical features of South Travancore differ as greatly from those of the adjacent part of South Tinnevelly as do the climates of the two districts. The flat, sandy, and often barren plains of Tinnevelly are replaced by a very broken, rugged country, out of which rise numerous hills and rocky ridges, the whole thickly covered by rich vegetation. With the exception of a couple of score of square miles immediately to the north of Cape Comorin, the whole of South Travancore lies westward of the watershed along the Southern Ghâts, which mountain range causes both the moist climate of Travancore and the dry climate of Tinnevelly, by intercepting from the latter practically the whole supply of rain brought by the south-west monsoon, and causing it to fall on their western slopes. A small tract around Cape Comorin, in the extreme south-east corner of Travancore, has a climate and shows a flora corresponding to the dry one of Tinnevelly. But within a very little distance to the westward a great change begins, and the climate and flora both assume an intermediate character, which may be traced over a tract extending from the Cape like a narrow wedge (in plan), having a base of some 20 to 25 miles along the coast, with its northern angle in the Arambuli pass. Close to the main mass of the mountains the change of climate and flora is far more abrupt, and really takes place within a distance of a very few miles, *e. g.*, near Mahendragiri, the most southerly high mass of the Ghâts (5,455 feet), where the change takes place in about 2 miles.

The country owes its shape to the erosion of the old crystalline rocks which has taken place on the most gigantic scale, proofs of which will be adduced further on. Dr. King, in his general sketch of the Travancore country, points out (p. 88) the *quasi-terraced* arrangement the country shows, descending by steps, as it were, from the mountains to the coast. This terrace arrangement is much less well marked, however, in South Travancore than further to the north-west. The several terrace steps are marked by the existence of some ridges near the coast higher than the general surface of the country further inland. The most conspicuous of these is a considerable mountain mass lying north and north-east of the old fort of Udagiri (Oodagerry).

[1] See *a.*—General sketch of the geology of Travancore State. By W. King, D. Sc., Deputy Superintendent (Madras), Geological Survey of India.

b.—The Warkilli beds and reported associated deposits at Quilon, in Travancore. By W. King, D. Sc., &c., (with a map). Records, Geological Survey of India, Vol. XV, pp. 87—102.

The real southern termination of the Southern Ghats occurs in north latitude 8° 15′, where the high mountains sink down into the Arambuli pass. Southward of the pass rises the perfectly detached Kathadi Malai, a fine rocky mass between 2,000 and 3,000 feet high, which sends off a rocky spur extending southwards with two breaks, for a distance of 7 or 8 miles, and terminating in the bold Murtawa hill, 4 miles north-west of Cape Comorin.. The Cape itself consists of low gneiss rocks, backed up by a palm-grown sand-hill, about 100 feet high. A pair of very small rocky islands rise out of the sea a few hundred yards east of the Cape, but they are not shown in Atlas-sheet 63, any more than are various other rocks occurring off the coast opposite Muttum[1], Kolachel (Colachull), and Mel Madelatorai (Maila Muddalathoray), which are the culminating points of reefs formed by ridges of gneiss running parallel with the coast. At Kolachel, which is the seaport of South Travancore, the lie of the rocks is such that it would be easy to connect them by short rubble breakwaters, and thus to form a very useful little harbour in which coasting craft could easily lie up during the south-west monsoon.

It will be seen by the map that a broken band of younger rocks occupies a very great part of the tract lying between the coast and the Trevandrum-Tinnevelly high road above referred to. There can be no doubt that these younger rocks not very long since, geologically speaking, formed an unbroken belt which extended considerably further inland than at present. The denudation they have undergone has been very great, both vertically and laterally, and the remnants of them left are in various places of such trifling thickness that all traces of their former existence will soon be effaced. They show most in the western part of the area under description, where they form small plateaux, which are well marked, except to the north, on which side they lap on to the rising surface of the gneiss and thin out, or are lost sight of, in the Kabuk or pseudo-laterite formation, a rock resulting from the decomposition of ferruginous beds of gneiss. The surface of the plateaux, where not greatly eroded, is gently undulating and often supports a very dense and varied vegetation. The less compact portions of plateau surfaces are often cut into small, but very deep, rain gullies which render many places impassable for any but foot passengers.

The most striking feature in the flora of South Travancore is the immense forest of fan palms (*Borassus flabelliformis*), which covers great part of the country. The fan palms, or palmyras, attain here to much greater height than they generally do elsewhere. Trees measuring from 90 to 100 feet in height are not uncommon in places, and, with their stems greatly covered by white, or silvery, grey lichens they present a much finer appearance than the comparatively stunted specimens one is accustomed to see in the Carnatic, or on the Mysore and Deccan plateaux. Whether these Travancore trees owe any part of their greatly superior height to superior age, as compared with the palms in the great palmyra forest in South Tinnevelly, I could not make out; but the white colour of their stems, added

[1] These rocks, and especially one called the Crocodile rocks, were sources of great danger to the coasting ships, but that has been removed by the erection on the Muttum headland of a light-house just completed.

to their great height, certainly gives them a much more hoary and venerable appearance.

To the westward of the Cooletorary river the palmyra trees are less striking features in the landscape than to the eastward. Cashew nut trees (*Anacardium occidentale*) are also very largely cultivated, and attain to greater size than anywhere in the Carnatic. Jack (*Artocarpus integrifolium*) and Alexandrine laurel (*Calophyllum inophyllum*) are also very common trees in South Travancore. Coco and Areca palms are commonly planted in the sides of the numerous little narrow valleys which score the face of the country, each with a rice flat in the bottom.

The backwaters at the mouths of the several rivers, and the canals connecting them, are often thickly fringed with screw pine (*Pandanus odoratissimus*); and a large fern, *Acrostichum aureum* (Linn.), is generally very conspicuous among the smaller bushes standing in the shallow water. One of the finest displays of tropical vegetation I am acquainted with in South India may be seen to great advantage by going in a canoe up the Cooletorary river for 3 or 4 miles from its mouth at Tengapatanam (Taingupatnum). The varying effects of dense lofty palm groves, interspersed with large forest trees and fringed with *pandanus*, &c., along the water's edge, and backed by the beautiful blue outlines of Agastyamalai and other peaks of the Southern Ghâts cannot fail to delight the eye capable of appreciating a series of perfect landscapes. Near the upper end of the navigable reach the beauty of the scene is increased by the presence of great granite gneiss rocks towering up here and there in the forest on either side of the river. Two other views, specially worth seeing, should be mentioned when describing the topography of this picturesque country. The first of these is due north from the bar at Mannagudi, 4 miles west of Cape Comorin. The eye here ranges across a large sheet of fresh water, set among palms, making a glorious foreground to the mountains which rise to the north, Mahendragiri and the great mass of the Mutukulivayal plateau standing out boldly. The second view to which I wish to draw attention is to be seen from the white rock spit about 1½ mile north-eastward of Cape Comorin. From here the south end of the ghats is seen across a lovely bay, with broken rocks and surf in the immediate foreground. The bright blue waters of the bay set off the fine tints of the nearer mountains to perfection, while the noble outlines of Mahendragiri and its companion peaks form a back ground of wonderful beauty. The view on a good day far surpasses the best of the views across Bombay harbour, about which so much has been written. From the Cape itself the mountains are not seen at all, being shut out by sand-hills, topped by a forest of palmyras.

In the foreground of the view from white rock spit the most characteristic trees are umbrella trees (*Acacia planifrons*), the most typical trees of the arid Tinnevelly plains, which are seen across the bay stretching away far to the north-east. A few miles to the west of the Cape these trees become very rare or have disappeared entirely.

Very conspicuous features in the landscape of South Travancore, as seen from the deck of a vessel passing off the coast, are several patches of intensely red rock or sand standing close to the beach, but perched up at a considerable height

above the water's edge. These are *teris*, or red blown sands, capping cliffs of red sandstone, both of which formations will be referred to at length further on.

The various geological formations to be found in South Travancore may, for convenience of reference, be arranged in a tabular scheme as below :—

RECENT	...	Blown sands: the red (teris), and the white (coast dunes). Soils; kankar deposits; ferruginous breccias (lateritic). Marine and estuarine beds.
TERTIARY	?	Sands and clays (Warkilli beds, ? Cuddalore sandstone.)
AZOIC	...	Gneissic series.

The Gneissic Series.

In no part of the peninsula, perhaps, is there a greater and finer display of the ancient crystalline rocks than in the Southern Ghâts in their southern half, and in the great spurs and outlying masses on their western or southern side. The disposition of the beds in South Travancore, when laid down on the map, shows the existence of a great synclinal curve, probably an ellipse, the major axis of which passes through, or very near to, the great mass of Mahendragiri; while the north-western focus (if the ellipse be a complete one) will be found somewhere to the north-eastward of Allepy. I had inferred the existence of this great synclinal ellipse from studying the course of the great gneiss beds on the eastern foot and flanks of the mountains southward of Courtallum, and Mr. King's examination of the gneiss country across the Shenkotta pass and southward to Travancore independently demonstrated the existence of the central part of this huge synclinal fold. The topographical shape of the ground, as shown in Atlas-sheet 63, points strongly to the fold being a true ellipse, the extreme north-western extremity of which is probably hidden under the alluvial bed north of Allepy, while the extreme south-eastern apex lies most likely in the sea to the E-N-E of Cape Comorin. The curve of the coast from Cape Comorin north-westward to close up to Trevandrum coincides with the south side of the great synclinal, and the different ridges inland also coincide absolutely with the strike of the harder beds of the series. Several southerly dips were noted in the rocks on the coast westward of Kolachel, which looks as if the axis of an anticlinal had there been exposed, but they may possibly only represent trifling Vandyke-shaped bends or crumples, in the side of the great synclinal. To the north of the area under consideration the rocks roll over northward into a great anticlinal fold.

The true bedding of the gneiss on a large scale is extremely well displayed in the great outlying mass known as the Udagiri or "Murroovattoor" mountain. Both strike and dip are admirably seen from the travellers' bungalow at Nagar Kovil. One of the finest examples of a sheer naked wall of rock to be seen in South India is shown in the tremendous cliff forming the S. E. front of the Tiruvuna Malai, the great eastern spur of Mahendragiri. This bare precipice must be fully 2,000 feet or more in height, many hundred feet in the central part being absolutely vertical, or even overhanging a little. As might be expected, this great mass has attracted much notice; it forms the Cape Comorin of some sailors, and of Daniel's famous view of that cape, though in reality some 16 miles

from the nearest point on the coast and 28 miles from the cape itself. Even the Hindu mind, generally so stolid about the beauties of landscape scenery, have connected this noble mountain with the name of Hanuman, the famous monkey god, who is said to have planted one foot on each of the two Peaks and to have jumped across the Gulf of Manar and alighted on Adam's Peak, a standing jump of 220 miles odd being a trifle for the long-tailed divinity.

Another grand precipice occurs on the south-east face of the Tadnga Malai, at the western end of the Arambuli pass. The cliff-faces in both these splendid scarps coincide with great planes of jointing.

The predominant character of the gneiss rocks in this quarter is that of a well-bedded massive, quartzo-felspathic granite gneiss, with a very variable quantity of (generally black) mica and very numerous small red or pinkish garnets. This is the characteristic rock at Cape Comorin, and very generally throughout South Travancore, and Tinnevelly district as well.

Scattered grains of magnetic iron are commonly met with in the weathered rocks. No beds of magnetic iron were noted by me, but some may very likely occur, and would go far to account for the enormous quantities of black magnetite sand cast up on the beach at frequent intervals along the coast and of which the source is at present unknown, unless it has been brought by the south-westerly current prevailing during the south-west monsoon. The source of the garnets which form the crimson sand, which is of nearly equally common occurrence, is not far to seek, for it is hardly possible to find a bed of rock which does not abound in garnets. The so-called "fossil rice" found at the extreme point of land close to the cape is merely a local variation of the quartz grains set free by degradation of the rock. They assume the "rice" shape after undergoing partial trituration in the heavy surf which beats incessantly on the southern coast.

The sub-aërial decomposition of the felspatho-ferruginous varieties of the gneiss produces in the presence of much iron a pseudo-laterite rock very largely developed over the gneissic area described by Dr. King in his Sketch of the Geology of Travancore under the name of lateritised gneiss, a rock which is popularly called laterite in Travancore and kabuk in Ceylon. In numberless places this peculiar decomposition of the gneiss, which is pre-eminently characteristic of very moist climates, has altered the rock *in situ* to variable, but often considerable, depths, and the original quartz laminæ of the gneiss remain in their pristine position, and often to all appearance unaltered, enclosed in a ferruginous argillaceous mass formed by the alteration of the original felspar, mica, garnets, and magnetic iron. The colour of this generally soft mass varies exceedingly, from pale whitish pink to purple, red and many shades of reddish brown and brown according to the percentage of iron and the degree of oxidation the iron has undergone. The bright colours are seen in the freshly exposed kabuk or pseudo-laterite, but the mass becomes darker and mostly much harder as the hæmatite is converted into limonite by hydration, and more ferruginous matter is deposited, as very frequently happens, by infiltration. The pseudo-laterite formed by accumulation of decomposing argillo-ferruginous materials derived from distant points is to be distinguished generally by the absence of the quartz laminæ as such. The quartz grains are generally much smaller, and are scattered generally through the

whole mass of new formed rock. One excellent example of the pseudo-laterite formed by the decomposition *in situ* is to be seen in a steep bank in the zoological gardens in Trevandrum, close to the Tapirs' den. Equally good examples are very common in many of the cuttings along the high road east of Trevandrum.

The washed-down form of pseudo-laterite often forms a rock intermediate in character between a true sub-aërial deposit and a true sedimentary one, and consequently by no means easy to classify properly. In fact, in a country subject to such a tremendous rainfall, the sub-aërial rocks must, here and there, graduate into sedimentary ones through a form which may be called "pluvio-detrital." Such pluvio-detrital forms occur very largely in South Travancore, but it is impossible in most cases to separate them from the true sedimentary formations they are in contact with.

The Warkilli or Cuddalore Sandstone Series.

The Cuddalore sandstone series, first distinguished on stratigraphical grounds as a separate geological group by Mr. H. F. Blanford, were by him supposed to be very probably of tertiary age. In the absence of sufficient palæontological evidence it was impossible to assign any more approximate position to these rocks, the silicified exogenous tree stems found at Tiruva-Karai, near Pondicherry, not being deemed of sufficient importance.

Other similar sandstone formations subsequently examined near Madras, in Rajahmundry district and on the Travancore coast near Quilon could, in the absence of all fossils, be assigned by myself and Dr. King only in a provisional way to the age of the Cuddalore rocks. Lithologically and petrologically these several sets of sandstones and associated clays, &c., show great resemblance, and their relative positions on or near the existing coast lines further justified their being provisionally associated, though separated by such great distances.

A very careful examination of the beds near Quilon by Dr. King, who had the advantage of seeing the fresh cutting made through plateaux of these rocks in connection with the new tunnel at Warkilli has unfortunately thrown no positive light on their true geological position. The vegetable remains associated with the lignite beds at base of the series proved insufficient to allow of determination of their own character, and consequently most unsuitable to assist in settling the homotaxy of the strata they occurred in. The sedimentary beds forming the belt of small plateaux fringing the coast of South Travancore must, on petrological grounds, be unhesitatingly regarded as extensions of the Quilon beds, or *Warkilli beds* of Dr. King. None of these formations which I traced from Villenjam, 9 miles south-east of Trevandrum, down to Cape Comorin, afforded the faintest trace of an organic body: thus, no light was thrown on the question of the geological age or homotaxy, but somewhat similar sandstones and grits are found on the Tinnevelly side of the extreme south end of the Ghâts range, and in a coarse gritty sandstone, much resembling some of the beds in Travancore, a bed of clay is intercalated, in which occur numerous specimens of *Arca rugosa* and a *Cytherea* of a living species. The locality where these fossils of recent species were found occurs on the right bank of the Nambi-Ar, about 2 miles above its mouth and a few hundred yards from the bank of the main stream. All the

sub-fossil shells I found here are of living species; hence the deposits enclosing them cannot be regarded as tertiary; and if the agreement of these Nambi-Ar beds with the Warkilli and South Travancore beds on the one hand, and the Cuddalore, Madras, and Rajahmundry beds, be assumed, as they must be on petrological grounds, the Cuddalore sandstones and their equivalents elsewhere must be accepted as of post-tertiary age. As far as it goes, the evidence is clear and distinct; but more evidence is required as to the age of some of the intermediate connecting beds, such as those south and east of Kudan-Kulam.

The typical section of the Warkilli rocks near Quilon, given by Dr. King, shows the following series:—

	Feet.
Laterite	30 to 40
Sands and sandy clays or lithomarge	58
Alum clays	25
Lignite beds	7 to 15
Sands	
TOTAL ...	120 to 138

with which we may compare the series seen in the fine section formed by the beautiful cliffs in Karruchel bay, 11 miles south-east of Trevandrum.

The section here exposed shows the following series of formations:—

	Feet.
4. Soil—dark red, sandy loam, lateritic at base	8 to 10
3. Sandstone—hard, gritty, purplish or blackish	?
2. Sandstone—gritty, rather soft, false bedded, often clayey in parts (lithomargic), variegated; in colour red, reddish-brown, purplish-white-yellow	40 to 50
1. Sandstone—gritty, rather soft, false-bedded, red, purple, pink, white, variegated; shows many white clay galls producing a conglomeratic appearance in section	40
Base not seen, hidden by sandy beach.	

The total thickness of these beds I estimated at about 100 feet; the upper part is obscure, from pluvial action washing down the red soil over the dark grits. The middle and lower parts of the section are extremely distinct, and the colouring of the beds very vivid and beautiful; but the beds are by no means sharply defined.

The beds dip north-easterly (inland), and from the slope of the ground on the top of the cliff the angle of dip may be inferred to be from 25° to 30°. Further inland, near Pinnacolum, the dark gritty sandstones lie horizontally, at a considerably lower level than at the top of the Karruchel cliffs, but rise again eastward. The middle gritty series is exposed along the western side of the Karruchel lagoon, but is highly lateritised by weather action. Three miles, or so, to the north of the lagoon, purplish gritty beds show strongly and form a small well-marked plateau overlooking the valley in which lies the village of Cotukall. That the gritty beds are sometimes replaced by clays is shown by the materials turned out of two deep wells sunk into this plateau at two points several miles

apart; one of these wells lies rather more than half a mile to the northward of Mullur (Mooltoor of sheet 63). Here the section, which is from 80 to 100 feet deep, passes through mottled gritty sandstone and into blue and white mottled clay. The other section revealing clays below the gritty beds is in a well sunk close to the new road from Valrampur (Vaulrampoor) to Puar (Powar), and some distance south of the place shown in the map as Vunpoyal[1]. The clay here is of a similar white and blue mottled colour.

A section in the low cliff forming the small bay immediately east of Villenjam shows a mottled vermiculated clayey rock showing mostly no bedding at all. Traces of bedding are, however, revealed as the cliff is followed southward by the appearance of thin bands of grit near the base of the section which rests on the underlying quartzo-felspathic garnetiferous gneiss. This mottled clayey rock I believe to represent the bluish-white-mottled clay turned out of the lower parts of the well section near Mullur before referred to. It is locally considerably discoloured and stained by the percolation of water through the overlying pseudo-lateritic, dark-red sand. As will be seen by any one who follows the coast line these Warkilli sandstones rest upon a very rugged and broken gneiss surface. Many great tors and knolls of granite gneiss protrude through the sandstone plateaux or tower over them from adjacent higher ridges, which have been completely denuded of the younger rocks.

The greater part of the surface of the tract occupied by these Warkilli beds west of the Neyar is thickly covered by sandy loam, generally of dark red colour, which conceals the sub-rock very effectually, excepting where the loam is deeply eroded. A well-marked patch of purplish grit forms a knoll, about a mile south-west of Valrampur. Traces of the former, more easterly, extension of these beds are to be seen at intervals along and to the north of the Trevandrum-Tinnevelly road between Valrampur and Neyatum Karai.

In the tract lying east of the Neyap few sections exhibiting the grits, &c., were met with, and all were small and unsatisfactory. The surface of the country is either largely covered with the deep red soil, or else the extremely broken surface of the gritty beds is extensively lateritised. The appearance of the country when seen from elevated points is, however, characteristically very different from the gneiss and kabuk tract lying to the northward. This may be well seen from Colatoor trigonometrical station hill, as also from the high ground close to Cauracode, but yet more strikingly from the Kodalam Pothia, a hill 2 miles west-north-west of Paurashalay. Sections in which the true character of the rock is to be seen occur on the high ground close to the junction of the new roads leading from Puar (Powaur) and Martanda Putentorai respectively to Paurashalay, also to the southward near Shoolaul (of map), where a large rain gully cuts deeply into the grits and underlying clayey beds; also along the ridge of high ground north and

[1] I failed utterly in identifying this and many other of the village names given on the map (sheet 63). It was very difficult to localise the positions of many phenomena I wished to record, even if landmarks existed on which to take bearings, owing to the extreme inadequacy of the map. The fact that the villages and hamlets generally straggle far and widely over the face of the country, instead of coinciding with any points indicated on the map, does not at all assist one in fixing one's whereabouts in the absence of landmarks.

north-east of the Yeldaseput of the map. Traces of the former eastward extension of the grits were noted on the eastern flank of the Kodalam Pothai, and on high ground half a mile or so to the northward of the cutcherry at Paurashalay. The beds composing this patch of Warkilli rocks have undergone greater superficial denudation than those in the Karruchel patch to the north-west.

In the small patch lying east of the Kuletorai (Cooletoray) river some instructive sections of hard dark grits and underlying clayey grits of the usual reddish, bluish, and white mottled colour are to be seen south of Killiur (Killioor). Some of the sections show regular miniature 'cañons' 15′ to 20′ deep, with vertical sides and numerous well formed pot-holes. Hard purplish grits show on the surface between Killioun and Pudukaddi (Poodoocudday) and soft mottled grits in a well section close east of the little D. P. W. bungalow at Tengapatnam, (Taingaputnum). At the southernmost point of this Killiur patch the grits become coarsely conglomeratic over a small area. A little to the north of this the grits, when resting on the basset edge of a bed of granular quartz rock, present the characters of a perfect arkose, made up of the angular gneiss debris. In places this arkose might be most easily mistaken for a granitic rock.

A distinctly conglomeratic character is shown by the grit beds close to Madalam (Muddaulum). This Madalam patch of Warkilli sandstones is on its southern side deeply cut into by a gully which exposes regular cliffs with from 35 to 40 feet of coarse or conglomeratic mottled grits, capped by thick red soil. The grits contain many large clay galls and lumps of blue or mottled colour.

In the Kolachel (Collachull) patch the grits are extremely well exposed in deep cuttings (miniature cañons) made by the stream rising just west of Neyur. They are of the usual mottled description. Where seen at the eastern side of the patch near the Eranil (Yerraneel) cutcherry they are quite conglomeratic.

They are exposed also in a gully crossing the road which runs north from Kolachel to join the main road, and in a well-section on the high ground a mile north-eastward of the little town. The south-eastern part of the patch is entirely obscured by a great thickness of dark red soil. They peep out, however, below the red soil at the western end of the great tank 3 miles south of Eranil (Yerraneel).

A very thin bed of conglomeratic grit underlies the *teri*, or red sand-hill, capping the high ground north of the Muttum (Moottum) headland. Further east a few poor sections only of whitish or mottled grit prove the extension of the Warkilli beds in that direction, nor are they well seen again till close into Kotar, where they show in various wells and tanks, but are still better seen in a deep rain gully south of the travellers' bungalow at Nagar Koil, and in a broad cutting immediately to the east of the bungalow. The variegated gritty sandstones here seen are very characteristic, and strongly resemble some of the typical varieties in South Arcot and Madras districts.

To the south of Kotar the grits are to be seen in streambeds opening to the Purrakay tank, and in a series of deep rain gullies on the eastern slope of a large red soil plateau to the south-west of Purrakay.

A small patch of gritty sandstones of similar character to the above occurs immediately north and north-west of Cape Comorin. As a rule, they are badly

exposed, being much masked by the red-blown sand of a small teri. The most accessible section is a small one seen in the bottom of a good-sized bowrie, a little south of the junction of the roads coming from Trevandrum and Palamcotta. This section can only be seen when the water in the bowrie is low. A considerable spread of similar greyish or slightly mottled grits is exposed about half a mile to the north-east of Cova Colum, and $1\frac{1}{2}$ miles north-west of the Cape. Lying between the two exposures just mentioned, but separated from either by spreads of blown sand, is a different looking vermiculated mottled grit of much softer character. This is extensively exposed in the banks of a nullah and head-water gullies falling into the Agusteshwar. The colour of this soft grit ranges from red, through buff to whitish. The beds roll to the northward. This grit is full of vermicular cavities filled with white or reddish kankar (impure carbonate of lime). The grit seems to graduate upward into a thick red gritty soil full of small whitish red, impure (gritty) calcareous concretions. There is good reason, however, for thinking that this graduation is merely apparent, and that the red gritty soil is only the base of a red sand-hill, or teri, undergoing change by percolation of calciferous water. A hard brown grit is exposed for a few square yards just north of the junction of the two roads above referred to. This rock has, except in colours, considerable resemblance to the red-white grit just described, and both probably overlie the pale mottled grits near Covacolum.

The last patch of grits to be mentioned forms almost the extreme easterly angle of the Travancore territory, and lies to the eastward of the southernmost group of hills and along its base. Not many sections of the grit are here exposed owing to a thick red soil formation which laps round the base of the hills, and is only cut through here and there by a deep rain gully or a well. The grits here seen are like those exposed near the travellers' bungalow at Nagar Koil, but show much more bedding and are almost shaly in parts. The colour of the grit is white, pale drab or grey mottled with red and brown in various shades. They lie in depressions in the gneiss, and were either always of much less importance and thickness than the beds to the west, or else have been denuded to a far greater extent. They are best seen in gullies to the south-west and west of Russhun Kristnapur, 7 miles north of Cape Comorin, and in the beds of the small nullahs west and north-west of Comaravaram opposite the mouth of the Arambuli pass. None of these Warkilli grit beds occurring between Trevandrum and Cape Comorin have yielded any organic remains as far as my research has gone, and I fear none will be obtained by subsequent explorers. The alum shales occurring in Dr. King's Warkilli section have not been traced in South Travancore, and I had not the good fortune to come across any lignite. It is said to occur not unfrequently to the south of Kolachel, and to be turned up by the people when ploughing their fields. I have no reason to doubt this, for it is extremely probable that some of the clayey beds should contain lignite. From the configuration of the ground, too, the paddy flatalong the southern boundary of the Kolachel grit patch would coincide in position with some of the clayey beds near the base of the series which are lignitiferous at Warkilli ; and why not at Kolachel?

The recent discovery of lignite in the Cuddalore sandstones at Pondicherry adds greatly to the probability of the correctness of Dr. King's and my conclusion

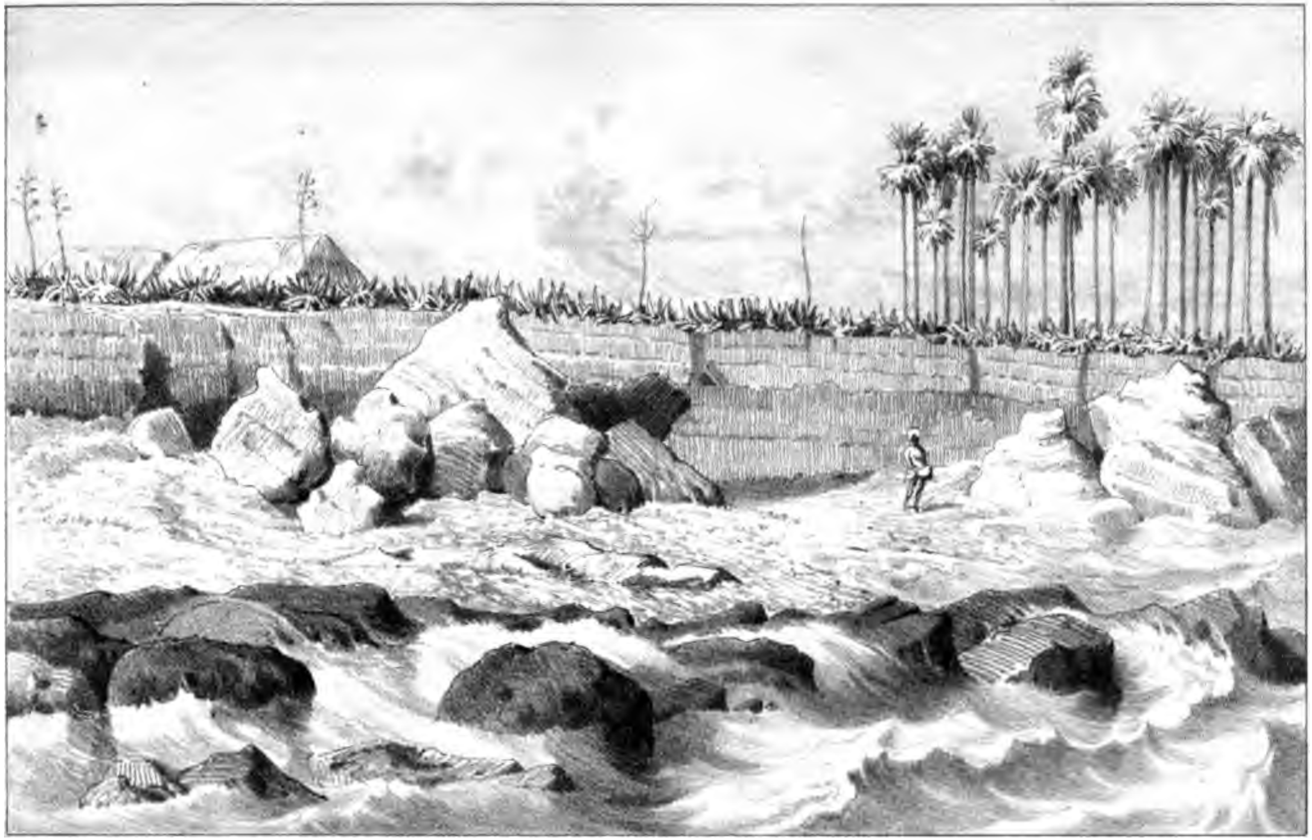
(arrived at by us separately and independently before we had an opportunity of comparing notes) that this gritty bed in Tinnevelly and Travancore should be regarded on the grounds of petrological resemblance and identity of geographical position as equivalents of the Cuddalore sandstones of the Coromandel coast.

The question of the age of these Cuddalore or Rajahmundry or Warkilli sandstones I propose to examine in the Memoir on the Geology of the Coastal region of Tinnevelly and Madura districts which I am now preparing.

The Marine Beds.

At Cape Comorin and two other places along the coast to the northward are formations of small extent but very considerable interest, which, by their mineral constitution and by the abundance of fossil marine shells they enclose, show themselves to be of marine origin, and thus prove that the coast line of the peninsula has undergone some little upheaval since they were deposited. These beds are to be seen close to the Cape at the base of a small cliff which occurs immediately south of the Residency bungalow, and only about 200 yards west of the Cape itself. The annexed plate is a truthful sketch of the little cliff, taken from a mass of gneiss rock projecting some little distance out to the south. The rocks seen in the surf, and immediately behind it on the beach, are all gneiss. The base of the small cliff is composed of friable gritty calcareous sandstone, full of comminuted shells. The base was not exposed at the time I examined this section, some heavy gale having piled up the beach sand against the foot of the cliff, and for this reason it was impossible to trace the probable connection of this sandstone with another exposed at a slightly lower level at a few yards distance to the west and just beyond the left-hand limit of the sketch. This lower bed is similar in mineral character, but very hard and tough, and offers great resistance to the surf, but has nevertheless been deeply honeycombed and in places quite undermined. The roof of the miniature caves thus formed have in some cases fallen in, but have been partly re-cemented by deposition of calcareous matter in the lines of fracture. To return to the cliff section, the basement sandstone is overlaid by a similar but slightly harder yellowish friable bed, which contains many unbroken shells (all of living species), in addition to a great quantity of comminuted ones. The base of the lower bed is hidden by sands, but from the proximity of the gneiss it cannot exceed 5 or 6 feet in thickness, while the overlying shelly bed measures about the same. It is overlaid in its turn by a massive bed, 6 to 10 feet thick locally, of a kind of travertine formed of altered blown sand, composed mainly of fully comminuted shells. This travertine contains immense numbers of shells and casts of *Helix vittata*, the commonest landshell in the south; it will be described specially further on. Owing to the soft character of the marine sandstones, the cliff has been much undermined by the tremendous surf which breaks on this coast in bad weather, and great masses of the hard travertine of the Helix bed have fallen on to the beach, as shown in the sketch, forming a partial breakwater against the inroads of the sea.

The shells contained in the upper sandstone bed were all found to be of living species, where sufficiently well preserved to admit of identification, the majority of the specimens are too ill preserved for specific identification. Four miles north-



CLIFF SECTION WEST OF CAPE COMORIN.

north-east from "the Cape," as it is locally termed, stands the little stone-built fort of Watta Kotai (Wutta Kotha), which is built upon a small patch of calcareous sandstone, full of marine shells, exposed in the moat along the north face of the long curtain wall which joins Watta Kotai fort with the extensive series of fortifications known as "the Travancore lines." The marine limestone may be traced for nearly half a mile inland in the bottom of the moat. This marine bed is overlaid by a very thin bed of travertine limestone full of *Helix vittata;* it has been cut through in the formation of the moat. The thickness of the shelly marine bed is unknown, but the Helix bed is not seen to exceed 10" or 1' in thickness. As far as seen in the very small exposure, both formations lie nearly horizontally. Another small exposure of the marine bed occurs at the western end of a little backwater (not shown in the map) to the north of the port. The sandstone here contains many well preserved marine shells, all of living species; but further west, where the bed is exposed below theHelix bed in the moat the enclosed shells are all broken and comminuted. The surface of sandstone, as seen at the end of the little backwater, is raised but a very little distance above the sea level, probably not more than 4 or 5 feet at the outside. The rise of the ground along the moat is extremely small, and even at the furthest point from the sea at which the sandstones are exposed the elevation is probably not more than 10 or 12 feet at most, which would correspond with the top of the sandstones as seen in the little cliff at Cape Comorin.

About 2 miles north-east-by-north of Wattakotai fort a small patch of white shelly limestone occurs peeping out of the low belt of blown sand which fringes the coast at that spot. The village of Kanakapur which lies immediately to the north is the last within the Travancore boundary. The limestone only stands out a few inches above the surface of the surrounding sands, and no section could be found to show its thickness, but in point of elevation above the sea level it agrees perfectly with the Watta Kotai and Cape Comorin beds. The limestone which is fairly hard is quarried for economic purposes, and unless a good deal more of the bed than now meets the eye remains hidden under the sands; it will, before many years are over, have been removed by human agency.

The shell-remains occur as impressions and casts of great beauty and perfectness, but the shelly matter has disappeared entirely, being probably slightly more soluble than the enclosing limestone. The limestone contains a large number of specimens of *Helix vittata* which were evidently carried out to sea and there entombed in a shallow water formation. To any one who has noticed the enormous numbers of this Helix living in this neighbourhood, and in the southern districts generally, the large number of it occurring fossil in this marine bed will be a matter of no surprise.

The Blown Sands.

Two very marked varieties of Æolian rocks occur along or near the coast of South Travancore, as well as along that of Tinnevelly; they are the red sands, forming the well known *teris* of Tinnevelly, where they are developed on a far larger scale, and the white sands forming the coast dunes. In South Travancore, as far as my observation went, the red sand hills are no longer forming; all are

undergoing the process of degradation by atmospheric agencies, at various rates of speed. The red sands have in many places ceased to yield to the influence of the winds and have arrived at a condition of fixity and compaction caused by the action of rain falling upon the loose sands percolating through them and during heavy showers flowing over their surfaces and washing the lighter clayey and smaller, though heavier, ferruginous particles down the slopes of the hills or into hollows on the surface, where, on drying, a fairly hard, often slightly glazed, surface of dark red loam has been formed. This loam is very fairly fertile and soon becomes covered with vegetation, which further tends to bind the mass together and render the surface secure from wind action. The loose sand, deprived of the clayey and finer ferruginous particles, would, unless unusually coarse in grain, be carried off by high winds elsewhere or remain in barren patches on the surface. I believe this process has gone on extensively over many parts of South Travancore, and explains the existence, on the surface of the country and resting indiscriminately on the gneiss and the younger rocks as the Warkilli sandstone, of the great thick sheets of pure red loam which have not been brought there by ordinary aqueous deposition nor formed *in situ* by the decomposition of the underlying rocks. The percolation of the rain-water through the mass has in many places given rise to the formation of concretionary ferruginous masses, which are often strongly lateritoid in their aspect. The quantity of clayey matter and of iron ore in the form of magnetic iron is very great in the sand of many of the teris. The greater quantity of the water falling on the teris, as on other blown sand surfaces, escapes by percolation, and it is a common phenomenon to find springs issuing around the foot of the sand mass during the rainy season and becoming dry in the hot or rainless season.

The teris in South Travancore which still retain their character as accumulations of moving red sands are four in number and all very small, the largest not measuring one square mile in area. They are all close to the coast and with one exception stand high and conspicuous to ships passing along at a fair distance. The largest and most conspicuous is that at Muttum which caps the high ground with the new light-house. The process of fixation has gone on here largely and the moving sands cover a much smaller space than does the fixed portion[1]. The same may be said of the teri resting on the south-eastern extremity of the Kolache (Colachul) sandstone plateau. To the north-west of Kolachel are two much smaller teris at the distances of 3 and 5½ miles respectively. In both of these also the area of the fixed sand far exceeds that of the loose. Especially is this the case in the more northerly teri near Mel Madalatorai (Maila Maddalaitoray). Here the fixed part has undergone tremendous erosion and is traversed by long and deep rain gullies, with vertical sides up to 20 or 25 feet high. Gullies on a yet larger scale are to be seen at the south-east corner of the Kolachel sandstone patch and at the eastern side of the Muttum patch. Very large but shallower gullies are to be seen at the south-east corner of the Nagarcoil patch, where there is a very large fixed teri.

[1] I have shown the extent of the unfixed or moving teris on the map; the fixed part I have treated as a soil and ignored accordingly.

The small teri immediately behind Cape Comorin is a very poor specimen of its kind, and, in fact, hardly deserves to rank as one owing to its pale colour and poverty in iron sand, but it will not do to class it as a coast dune, as it consists mainly of silicious sand, while the true dunes at the Cape consist mainly of calcareous sand composed of comminuted shells, corallines, nullipores, &c.

The sand of the typical teris is silicious or ferruginous (magnetic iron), the former being well rounded and coated with a film of red oxide of iron, which is removeable by boiling in nitric acid for a few seconds. Common as garnet sand is on the beaches of South Travancore, I never yet found a grain of it in the teri sand, where the latter was pure and had not been mixed with beach sand. Much difficulty exists as to the source whence the red sand was derived; but I will not attempt to discuss this question here, as I hope to treat it at much greater length than I could now, in a Memoir on the Geology of Tinnevelly and Madura districts which I have in preparation.

The coast dunes of South Travancore are, except close to the Cape, in no way remarkable. A large patch of small hillocks to the north-west of the mouth of the Kuletorai (Cooletoray) river was caused by the wind shifting a great mass of sand turned out when the new canal was dug and heaped up on the north bank of the canal.

Some tolerably high ridges occur 3 miles south-west of Kolachel. The sand here contains so much fine magnetic iron that it looks in parts of a dark grey colour, shading here and there almost into absolute black.

A considerable quantity of blown sand fringes the coast from the Muttum headland eastward to Cape Comorin, and between Pullum and Culladevella forms some considerable hills. At Covacolum the highly calcareous beach sand which forms many low hillocks has been solidified in several places into coarse shelly limestone. The Helix bed at Cape Comorin already referred to, when treating of the Marine-beds, is really an altered sand dune, the calcareous matter of which has, by percolation of acidulated water, been dissolved and re-deposited, on evaporation of the water, as a subaerial travertine. Countless thousands of *Helix vittata*, and a considerable number of shells of *Nanina tranquebarica*, the two commonest land shells in this part of India, have been inclosed and fossilised in the formation of this travertine, which is evidently in constant progress. The immense wealth of shellfish of all kinds, added to large quantities of corallines and nullipores, incessantly thrown up by the surf, furnishes an abundant supply of calcareous sand for the formation of this travertine, which forms a bank more than a mile long and rising some 80 feet or more above the sea at its highest point. Its inland extent cannot be ascertained, as it is covered by loose sands. It probably only extends 300 to 400 yards inland and abuts against a low ridge of gneiss.

Coral Reefs.

A few tiny fringing reefs are to be seen half to three-fourths of a mile west of the Cape, half in the surf at low tide, and wholly in it at high tide. They are now to be considered as dead reefs, abandoned by the polypes that built them. I examined most of them carefully, without finding any live coral, and was inclined to doubt the correctness of my inference, drawn from their tabular shape and many shal-

low basin-like cavities; but later on, when examining some identical fringing reefs off the Tinnevelly coast to the south of Kudung Kulam trigonometrical station (the south point of the Cape Comorin base-line), I found a considerable quantity of live coral lining the sides of the little basins, and equally large quantities of coral quite recently dead in adjoining basins.

A great deal of shell debris, sand and broken stone, is included in the mass of the reefs which in several places have formed around masses of rock standing in rather shallow water, and joined up many loose blocks of stone tossed on to them by the surf into tremendously coarse conglomerates. Some similar reefs, but of rather larger size, occur along the coast to north-east of Cape Comorin; in these the tabular mass extends from 10 to 40 and 50 feet in width, from the shore to the constantly surf-beaten outer edge. In one or two places parts of the reef had evidently been founded on sand, which had been washed away, leaving an unsupported surface of many square yards in extent, which the surf of the next high tide or first gale of wind would either break up or else again support with sand washed under it. These little reefs are worthy of much closer examination than I was able to bestow upon them.

The coral fauna of the Cape Comorin sea is on the whole a remarkably poor one, as far as one may judge by what is to be found thrown up on the beach. Dredging might reveal much more, but unfortunately no boats are to be found there, only Kattumarams (Catamarans), which would not be the most convenient form of craft from which to carry on scientific observations. The sea here is, however, so very rich in animal life in many forms, that it would assuredly afford a rich reward to any one having a suitable vessel at command. I obtained in a very short time a far larger number of species of shells here than at any other place on the Indian coast.

Soils.

The prevalent soils are red ones, varying in the quantity of their ferruginous element. The red soils seen inland near the main trunk road are chiefly formed of gneissic debris by subaerial decomposition. The origin of the deep red sandy or clayey loams has already been discussed (*ante*, page 32). They occupy no inconsiderable area. True alluvial soils occur very rarely, if at all, now-a-days; those which fill the bottoms of the many valleys and creeks in which paddy is cultivated being greatly altered from their original condition by centuries of cultivation, and the addition of various mineral, vegetable, and animal manures. Estuarine beds full of subfossil shells, *Cytherea*, *Pottamides*, *Melania*, &c., of living species are exposed in the salt pans at the mouth of the Kolachel nullah.

The alluvium in the valley of the Paleyar, which flows south from the west flank of Mahendragiri past Nagurkoil, is, where pure, a coarse gritty silt.

Economic Geology.

Valuable minerals and metals are conspicuous by their absence in the part of South Travancore I had the pleasure of exploring. I came across no sign of any mineral industry, except the preparation of sea-salt in the pans near Kolachel, and traces of an old iron smelling industry carried on formerly at foot of the now


Morques
Choultry
Chettimaun
Pillincoorchy
Choultry
Mundragherry
Panthypoody
R.S.
Punnaugoody
Annantawaram
Ullya Pandeveram
Mulhoor
Yerrabyboodoor
Poodoopandy
Moopundalmuttum
Sheedapall
Permaupoorum
Aramboly
Grilly's S.S.
Shemboogaramanboodoor
Fanlagoody
Toovaula
Auveriolum
Pooliarcoody
Shandanadapooram
Pullauoor
Ramnatapoorum
Wuddashairy
Paurpullipoorum
Nagarcoil
Ramaoorum
Calniyapoor
Ullaganapoorum
Kurungodium
Ramesweram Gate
Kistnapur
Kotar
Tairoor
Shoosheendrum
Shoorungoodi
Purrskay
Perrincolum
Mundarumboodoor
Colarum
Agrarum
Wurioor
Kanakapur
Taunmalanboodoor

bare and rocky hills east and north-east of Myladdy and some 7 miles north-west-by-north of Cape Comorin. Judging from the large quantity of iron slag here remaining, the smelting industry must have been an important one for native workmen. I could get no information about it on the spot. I met with no existing iron smelting industry in the villages I traversed, probably because of the absence of rich supplies of iron ores. The supply of beautiful building stone is practically unlimited, but not much use seem to have been made of it. Travancore architects seeming to prefer the use of wood, the chief large stone buildings are the extensive fortifications erected to bar the way into the country from the eastward, and known as the Travancore lines. They are mostly built of gneiss, Wattakotai port already referred to being a very fine example of excellent well-cut masonry. At the extreme south end of the lines, where they abut on the sea near Cape Comorin, blocks of the marine sandstone have been employed in the walls to some extent, but have been much affected by weathering. The old fort at Udagiri (Oodagerry) is another extensive stone building.

Of the temples, which are usually fine specimens of stone work in South India, I have nothing to say. Non-Hindus may not approach them for fear of rousing the fury of the ultra-bigoted Brahmans, who unfortunately retain far too much power in Travancore, and exercise it to the detriment of the country generally.

Some of the hard sandstones of the Warkilli series have been used for building to a limited extent, and I noticed not far from Puar a good example, perfectly new, of a stone cattle-trough cut out of homogeneous pale, purple and white, hard lithomarge of very jaspideous appearance. I did not see a similar rock *in situ*, but it evidently came from some bed belonging to the Warkilli series.

Some notes on the Geology of Chamba *by* COLONEL C. A. McMAHON, F.G.S.

I propose, in the present paper, to give the results of some tours in the mountains adjoining Chamba, in continuation of my papers "on the geology of Dalhousie," and "on the section from Dalhousie to Pángi"; and I pre-suppose, on the part of the reader, a knowledge of the facts recorded in those papers.

In the first instance, I shall ask the reader to accompany me from Basaoli, over the Bánjal (Banjil) and Chattar Dhár passes, to Bhadarwár (Badrawar).

Leaving Basaoli, the Siwaliks continue with a steady N.-E. 5° E. dip all the way to Bhond (Pood). About half-way to the latter village, the coarse conglomerates of this series give way to red clays and massive sandstones, which in their turn are succeeded, near Bhond, by a fine-grained conglomerate, corresponding to the topmost Siwalik beds of the Dancra-Dalhousie section.

At Bhond, the Siwaliks dip under indurated red clays and fine-grained sandstones of dark-grey colour. Both the clays and the sandstones are full of fine specks of a silvery mica. These rocks, I presume, represent the Dagshai and Kasauli groups of the Sirmur series. They dip N. 11° E., and extend as far as Seloo.

These beds are followed by a massive quartzite of whitish colour, dipping east and then by the slates and limestones of the carbo-triassic series, which have also an easterly dip. The limestones are the ribbed variety previously described, and

they continue to the top of the Bánjal pass, the elevation of which is, according to my aneroid barometer, 6,325 feet above the sea. At the top of the pass the rocks dip S.-W. 11° S., but the dip is high and nearly vertical. The carboniferous slates become very black as the gneiss is neared.

About 2 miles below the top of the pass, on the northern side, the first outcrop of gneiss appears. The rock, as seen in this section, is a thoroughly crystalline gneiss, but it is never granitoid. Its dip is nearly perpendicular. The gneiss continues down to the Sewa river,—the river that flows from the Chattar Dhár into the Ravi,—and as the stream is approached the dip becomes more moderate.

On the descent to the Sewa there is a bed or dyke of fissile trap, about 20 feet wide, in the gneiss. It appears to be a decomposed diabase. It is of greenish-grey colour and its specific gravity is 2·95. Under the blowpipe it fuses readily to a black magnetic bead. The microscope reveals pieces of still unaltered augite here and there. Felspar may be traced in it, but it is greatly altered. A banded, or pseudo-foliated appearance, observable in this rock, is due probably to the infiltration of water along lines of cleavage due to traction or pressure. Along these lines minute granules of quartz—some of them of elongated form—are visible. This mineral is doubtless a secondary product. The quartz does not contain any fluid cavities which are very abundant in the quartz of the gneiss.

At the point where the road strikes the Sewa, the gneiss is succeeded by blue, micaceous slate, and as Bani is neared, the dip of the strata reverts to N. 11° W. The schistose rocks are of a type commonly seen in the neighbourhood of Dalhousie (as, for instance, on the road to Chuári), crumbling to a soft bluish-white powder, suggestive of french-chalk.

The outer band of gneiss is, in this section, some thousands of feet thick.

I observed no outcrop of the trappean zone in this section; it has apparently either thinned out, or has been cut off by a fault.

Schistose rocks, dipping N.-E. 15° N., all of which could be matched in the Dalhousie area, continue from Bani to Loong, where the "central gneiss" crops out on the right bank of the Sewa. It runs thence in a nearly straight line, following the direction of the river and keeping on the right bank through Chunchli (Chounchli), and crosses the Sewa some distance above the last-named village.

At first the slates, in contact with the "central gneiss," dipped E. 11° N. *away* from the granitic rock, but afterwards they became perpendicular.

The granitoid gneiss here is a porphyritic and perfectly granitic rock, much traversed by joints, but I could not make out any bedding. At one place I noticed that it had intruded between the bedding of the slates. It continues for some miles, when the slates re-appear, dipping N.-E. 11° E. *away* from the granite. The road, from this point, runs, almost along the boundary of the granite and slates, up to the top of the pass (elevation 9,650′). The granite is never far from the road, on the right bank of the stream; whilst the slates are seen on the left bank all the way up.

The granitoid gneiss continues to be seen on the left of the road for about

$2\frac{1}{2}$ miles down the north side of the pass. From this point the slates continue down to Bhadarwár. The dip remains unchanged.

The Kund Kaplás (Koond Kaplas), in many respects, seems to be an analogue of the Chor mountain of the Simla area. It is 14,241 feet high, the elevation of the Chor being 11,982 feet; and like the Chor it abuts on the plains and appears to be formed of "central gneiss." It will be seen from the observations made on this tour, that the "central gneiss" suddenly expands to a great width of outcrop as the "Kund Kaplás" is neared.

My route now leads back over the Padri[1] pass. The rocks seen *en route* are slates, and on the ascent of the pass they are quite typical "Simla slates;" dip, N.-E. 5° N.

About two-thirds of the way between Thanala (Tenala) and the top of the pass (elevation of top 9,700′), I encountered my old friend, the "Blaini conglomerate." It is quite typically developed, and the detailed description given of it in my paper on the Dalhousie and Pángi section applies equally well to the rock seen in this section. On the conglomerate there rests, 975 feet below the summit of the pass, about 50 or 60 feet of pale-blue limestone. Above the limestones slates re-appear.

On the descent of the pass, going east, the slates are vertical, or nearly so, having a very high dip, sometimes in the normal, or north-easterly direction, and sometimes in the reverse direction. This variable underlie prevails, along the line of strike, in an easterly direction, as far, at any rate, as Manjir.

The conglomerate re-appears on the road side, about half a mile below the top of the pass. It runs thence to near Langera (Langaira), almost in a line with the road, cropping up on the road side more than once. Near Langera the outcrop is of great thickness.

Where the road, near Langera, descends to within a few yards of the river, the conglomerate contains a boulder of granitoid gneiss 1′ 3″ long. Mr. Lydekker has already noted the presence of granitoid gneiss[2] boulders in the slates of the Pángi-Lahoul valley; and the discovery of a similar boulder in the silurian conglomerate, on this side of the snowy range, is interesting and important.

I saw numerous blocks of pale-blue limestone, weathering buff, in the vicinity of the conglomerate, between the top of the pass and Bhándal (Baundal), but I doubt if any of them were *in situ*. They probably indicate the presence of the carbo-triassic series in the mountains which bound the north-eastern side of the Siul[3] valley.

The conglomerate continues in the same general direction as the river the whole way to Bhándal. I counted ten outcrops of it, *in situ*, on the road side, between Langera and Bhándal. Some of these outcrops run with the road for a considerable distance.

[1] This word is not Pádri, but Padri, which means flat.

[2] The presence of granite, or syenite, boulders in the conglomerate at Gurais, in Kashmir, is also noted by Mr. Lydekker at p. 24, Vol. XII, Records.

[3] Kundi Marál (Kandi Marl), the name entered on the map, is not the name of the valley, as one would suppose, or the name of the river that runs through it, but the name of an encamping ground, where the peg to which a Raja's horse was tied is said to have grown miraculously into a big tree. Hence the name.

A calcareous band (weathering buff[1]) crops out about 4 miles to the S.-E. of Prangal (Prungli), and re-appears several times afterwards.

To the east of Bhándal the conglomerate runs with the road for some distance.

It will, perhaps, conduce to clearness, if I note in this place the several outcrops of this rock which I have, up to date, noted along the line of its strike in an easterly direction. On the ascent of the ridge between Dihur (Duire) and Manjir, the conglomerate crops out on the road side, and, crossing the ridge with the road, descends to the river between Manjir and Kandla.

In my paper on the Dalhousie and Pángi section, I did not note the occurrence of the conglomerate on the left bank of the river to the east of Manjir, as, owing probably to the predominance of vegetation, I did not see any outcrop *in situ;* but the conglomerate, I doubt not, in its eastward extension, passes somewhere in the neighbourhood of Balore.

I came across another good outcrop of the rock in the mouth of the Hulh (Hul) valley, (immediately north of Chamba), between the villages of Baroar and Chambi. Proceeding eastwards from Chamba up the Ravi river, the conglomerate again appears on the road side at the bend of the river, a little to the east of Gun (Guar). It continues thence in a nearly straight line to Chitráli (Chitralri) and Sowala, and curving round above Naukula, it passes a little above Aulansa (Hulans), and thence a little to the north of Grima, onwards through Suchai and Bauri (near Barmaor) to Poulda and Kund.

I have noted numerous outcrops along the line indicated, but it seems needless to describe them in detail. The country between the outcrops near Manjir and in the Hulh valley, and between the latter and Gun on the Ravi, I have not yet explored. I have, also, not been to the east of Harser, as the route I followed took me towards the sacred lake of Man Mhaish (Manimais).

It is interesting to note the continuous outcrop of the upper-silurian conglomerate along a line parallel to the granitoid gneiss, as it confirms the conclusion previously arrived at, that we have in the Dalhousie-Chamba section a normal sequence of silurian rocks resting on the granitoid gneiss.

Between Chamba and Dancho the dip is north-easterly. Near Harser, the dip, which had previously been moderate, becomes vertical, but between Harser and Dancho it again subsides into a N. E. dip.

Between Chamba and Mahila (Maila), the granitoid gneiss crosses to the right bank of the Ravi, at the bend of the river under Tandola, re-crossing to the left bank near Bania. It passes to the right bank, again, beyond Bania, and then continuing its course under Dalgara and above Korauh, it finally leaves the river near Mahila.

At the junction of the granitoid gneiss and the slates, the former is granitic and the latter is indurated, and sometimes silicious and massive. Under Dangera (Dalgara), near the junction of the two rocks, the slates are contorted, and there is a sudden reversal of dip, with more or less local faulting. At the actual

[1] Blue limestones, weathering buff, is a peculiarity which appears to be common to several bands of the carbo-triassic series and the Blaini limestone. It does not help to distinguish the two series.

junction the dip of the slates is normal. The plane of division between the schistose slates and the granitoid gneiss is not sharp, but the granitoid gneiss appears to be blended into the slates by imperfect intrusion.

I now ask the reader to return with me to Chamba, and accompany me up the Hulh valley.

Up to the outcrop of the conglomerate, between Baraur and Chambi, the rocks are silurians and the dip normal. After Chambi, the path (there is no made road, and consequently no good road-side sections) lies along a fertile and well-wooded valley. Vegetation is rich, and rocks, *in situ*, are only to be seen here and there. I saw no outcrop of limestone.

A little to the north of Hulh, I came upon trap resembling the Dalhousie rock, and it extended to about the level of Bhaloth (Balote). As I am not, at present, sure whether this outcrop of trap occurs to the north or to the south of the carbo-triassic series seen in force south of Kalel (Kalail), on the Chamba and Tisa road, I reserve further remarks on this section until I can explore the mountains round the Rundhurst station.

My route now lay up the Hulh valley, over the high ridge at its head, and thence down to Kalel. I was able to trace the boundary of the carbo-triassic series and the conglomerate. The latter runs a little to the north of Sairu, and continues parallel to the river, striking towards the ridge that terminates at the bifurcation of the stream. Numerous blocks of typical conglomerate fill the bed of the stream.

The section from Kalel to Tikri has been already described. My route now lay from Tikri to Himgiri (Himgir), and thence round the Himgiri station to Digi and Dihur, and back again along the river to Himgiri. The rocks about Tikri are silurians—micaceous schistose rocks, crumbling to a whitish soapy powder.

The northern boundary of the conglomerates runs a little south of Tikri (not the village above alluded to, but another village of the same name under Himgiri), and thence to Laura towards the Himgiri station, which it leaves a little on its right. The southern boundary of the conglomerate crosses the ridge west of Kalel at Dhar, and continues thence up the Gulel (Gulail) valley. I met with typical outcrops of the rock on the ridge east of Bila (under the Himgiri station), and again along the ridge above Gulel. I found another good outcrop on the ridge between Gulel and Tiloga.

The dip is normal until Himgiri is neared, when a S.-S.-W. dip sets in. To the west of Himgiri, this changes to a S.-W. 11° W. dip, and then becomes nearly perpendicular. Beyond this, the dip reverts to the N-E. Further on, it becomes high and wavers occasionally to the south-west, but eventually settles down to a N.-E. dip.

In contact with the conglomerate, a trap, similar in its general appearance[1] to the Dalhousie rock, crops up along the ridge dividing the Gulel from the Tiloga valley. The outcrop is of considerable thickness, and in its S.-W. extension

[1] I have not as yet examined thin slices of it under the microscope.

it dominates the ridge running down to Dihur, in the neighbourhood of which village it either dies out or is cut off by a fault. The outcrop appears to widen in its northerly extension, and it is evidently present in force along the high ridge N. E. of Bhandal, the streams flowing down from which are full of boulders of trap. The western boundary of the trap runs a little to the east of the villages of Tiloga, Baroga, Kalsara, and Chikotra.

Following the road from Dihur to Himgiri, I found that where the road crosses it the outcrop is still of considerable width. It crops out at no great distance from Dihur, and extends to near the village of Dalui. On following a low-level path, near the river, as far as the stream to the north of Banjwar, however, I found that the trap does not extend as far east as this village.

Along the south-western boundary of the trap, the latter is in sharp contact with the limestones of the carbo-triassic series. This is well seen on the road leading from Dihur to Himgiri, where the limestones, which dip about N. N. E., are in great force. Both the trap and the limestones are typically developed, and the latter do not appear to be at all altered at their junction with the trap.

The limestone series is also well seen along the crest of the ridge north of Manjir. It crops out a little south of Nandla, and extends as far as Dhar. The dip, which is variable when the limestones first appear on the crest of the ridge, soon settles down to a N.-E. 5° N. dip. Some of the limestones are pale-blue, some creamy-white, and a few are of a deep dark-blue colour. Some of them weather to a rusty buff. I saw numerous blocks of limestone along this ridge crowded with crinoid stems, but I did not observe any *in situ*.

In connection with the trap above described, a variety occurs, which I have not observed elsewhere in the Himalayas, but which probably represents the porphyritic trap of Kashmir described by Mr. Lydekker. It is a felspar porphyry, an intensely hard rock; so hard that it was with extreme difficulty that I could obtain hand specimens of it. Boulders of it are brought down by the stream from the ridge N. E. of Bhándal, together with boulders of the ordinary variety of the trap. I have not yet seen it *in situ*.

Conclusion.—The observations made this season confirm the conclusion previously arrived at, that we have, in the Dalhousie-Chamba section, a normal sequence of silurian rocks resting on the "central gneiss." The "Blaini" conglomerate (upper-silurian) and the "Simla slates," of the Simla region, are both represented in Dalhousie-Chamba area; the conglomerate cropping out in a continuous line parallel to the granitoid gneiss.

The upper-silurian conglomerate is followed, in the Bhándal-Dihur region, by the carbo-triassic series, resting apparently conformably on it; but if the view taken of the age of the trap in the Dalhousie area in my paper on the geology of that region is sound, the boundary between the two series must really be a faulted one. The thinness of the conglomerates on the south side of the carbo-triassic limestones, as compared with their great development on the northern side of the limestone outcrop, is a fact which, to some extent, favours the fault hypothesis.

In the Bhándal-Dihur area, under consideration, the carbo-triassic limestones are followed by trap, and the latter by the upper-silurian conglomerate and a normal sequence of silurian rocks in inverse order.

In the Dalhousie area, the trap comes in between the carbo-triassic series and the tertiary rocks. In the Bhándal-Dihur area, it comes in between the carbo-triassic series and the upper-silurian conglomerate.

In my paper on the geology of Dalhousie, I adopted the hypothesis that the trap is of upper-silurian or pre-carboniferous age. I see nothing in the facts recorded in this paper inconsistent with that hypothesis. Indeed, I may say that when I formed my views regarding the age of the trap, I had distinctly before my mind's eye the possibility that trap might be found in the Bhándul-Dihur area, where I have since found it. I thought this possible from the fact that the Siul river under Manjir is full of trap boulders.

In both the Dalhousie and the Bhándal-Dihur areas the trap is found in contact with the carbo-triassic series; whilst in the latter section, it is in sharp contact with the upper-silurian conglomerate on the one side, and the carbo-triassic limestones on the other.

The fact that, in the Bhándal-Dihur section, the trap does not occur between the carbo-triassic series and the upper-silurian conglomerate, on both sides of the limestone outcrop, may I think be explained by the hypothesis of a fault between the limestones and the southern outcrop of the conglomerate.

The Bhándal-Dihur section, from the granitoid gneiss, south of Bhándal, to the lower-silurians, north of Bhándal, seems to me to be a crushed synclinal fold, complicated with faulting. That there is a fault somewhere seems self-evident. Whether the trap is of pre-carboniferous or of post-carboniferous age; in either case there must be a fault between it and the upper-silurian conglomerate.

The simplest mode of explaining the section, it seems to me, is to put a fault between the southern boundary of the limestone outcrop and the southern outcrop of the conglomerates; we should then have a normal ascending series of rocks from the "central gneiss" to the upper-silurian conglomerate, and a descending series of rocks from the carbo-traissic limestones to the lower-silurian schists. In short, I believe that we have in this section a crushed synclinal fold, with a fault along its axis, the compression of the folded strata having been great enough to produce a general conformity of dip.

In the Hulh section, I have some grounds for suspecting that the trap occurs between the southern outcrop of the conglomerate and the carbo-triassic limestones; but should this surmise prove correct, the point is immaterial as far as the hypothesis above propounded is concerned.

The observations made this season show that the outcrops of trap are not continuous; but whether this is due to faulting or to thinning out, I am not at present in a position to say. Either supposition seems equally probable.

The discovery of a boulder of granitoid gneiss in the upper-silurian conglomerate of the Bhándal region, taken in connection with the discovery by Mr. Lydekker of similar granitoid gneiss boulders in the silurian slates of the Pángi-Lahoul area, is another indication of the connection between the rocks of the two regions;

and, on the supposition that the granitoid gneiss boulders were derived from the "central gneiss," which Mr. Lydekker apparently does not now doubt[1], the fact supports the conclusion I arrived at for the Simla area, that a hidden unconformity exists between the silurian and the "central gneiss" series. A similar conclusion was drawn by Mr. Lydekker in his fifth paper on the geology of Kashmir.[2]

On the Basalts of Bombay, *by* COLONEL C. A. McMAHON, F. G. S. *(with two plates).*

During my last visit to Bombay, I made a carefully selected collection of typical specimens of the lavas exposed at different parts of the island, and I have since studied thin slices of them under the microscope.

I think it will be worth while to give a brief description of these; partly as the first contribution towards a better knowledge of the Deccan traps, regarding which our petrological information is at present very deficient; and partly because the description of the very typical lavas of Bombay may be useful as a standard with which to compare more doubtful basic igneous rocks in other parts of India.

I arranged the specimens which I am about to describe with sole reference to their colour. They range from iron black through less and less dark shades of grey to a greenish-grey colour.

In specific gravity the specimens vary very little, ranging from 2·80 to 2·85, their average being 2·82. They are all remarkable for the absence of olivine. Augite, plagioclase, and magnetite are present in each slice. All contain a few crystals of sanidine, but it occupies an extremely subordinate position.

No. 1.—*A dark-grey, almost black, compact rock.* Sp. G. 2·82.

M.[3]—This slice consists of a net-work of very small felspar prisms, and minute granules of augite, starred about in a partially devitrified glassy base, with moderately large crystals of felspar and augite sparsely scattered through it. The base is brownish-green, dappled with white, in reflected light, and olive-green in transmitted light. The white opaque material is, I think, leucoxene, a secondary product resulting from the decomposition of ilmenite, though in the particular slice there is no direct evidence of its connection with that mineral.

The felspar prisms, for the most part, present very sharp outlines, and the great majority of them are seen to be triclinic. They contain numerous glass cavities, many of which have fixed bubbles. Some of these glass enclosures are elongated, others are in rounded forms. The presence of such cavities is considered by Dr. Sorby to indicate the true volcanic origin of the rock containing them (Q. J. G. S. XXXVI, 49, 53). In one of the prisms, the glass enclosures have ranged themselves roughly in a zone conforming to the shape of the prism. Other prisms contain portions of the glassy base caught up in them.

[1] Records, XIV. 42. [2] *Ib.*

[3] In this and following papers M stands for microscopic aspect.

Augite crystals are extremely abundant, and most of them are of very minute size. Among the larger crystals twinning is common, and some are well shaped. In transmitted light the augites exhibit a faint tint varying from greenish-yellow to yellowish-brown, but so faint as to be almost white. This is the predominant colour of the augite in all the slices.

The augite and felspar appear, on the whole, to have crystallised at the same time, though some individuals have formed before the others. In fig. 1, plate II, I have given a sketch of a couple of augite crystals of irregular shape, joined together in a manner suggestive of twinning, which have formed round a felspar prism; whilst in fig. 2, plate II, I have depicted a group of triclinic felspar prisms, which have formed upon, and partially enclosed, a cracked augite crystal.

The augite and felspar in this slice are remarkably fresh. This is a characteristic of the augite in all the Bombay slices.

Magnetite is present in some abundance, both in regular shaped crystals and in the skeleton forms described in my paper on the Darang traps. Some titanic iron (ilmenite) appears to be also present.

In fig. 1, plate I, I have given a sketch of a portion of this slice, as seen in the field of the microscope, under a magnifying power of 60 diameters. The outline of the felspar crystals is generally sharp,—an indication I think that the lava was in a very fluid condition. Towards the centre of the field a rather large augite crystal is represented. On three sides the prismatic faces may be traced, though they are not well depicted; whilst the crystal may be seen to be traversed by rather irregular prismatic cleavage lines. Cracks are sometimes of use and furnish indications, in a general way, of the direction of the cleavage. A large crack in the crystal under consideration affords an illustration of this. For some distance it follows the direction of one set of cleavage lines, and then changing its course follows the direction of the second set, which crosses the first at an angle (87° 5′) approximating that of a right angle.

A crack traverses the slice and appears to have been filled up by an exfiltration process; the material it contains being cryptocrystalline.

No. 2.—A compact, dark-grey, almost black rock, closely resembling the last Sp. G. 2·82.

Under the pocket lens it has a somewhat vitreous lustre, and small facets of felspar are to be seen in it here and there.

M.—This slice is so like the last one that it hardly requires a separate description. The glassy base is whitish in reflected, and brown in transmitted light. Here and there it has been altered to a dull olive-green substance, which, when a single nicol only is used, transmits little light. In places it is stained brown-yellow to orange colour,—a result doubtless of the decomposition of magnetite.

Felspar is even more abundant than in the last slice; and here and there crystals of it are of comparatively large size. Glass and stone cavities are common in the felspar, but I discovered no bubbles in them.

Augite is fairly abundant. Its shape is irregular, but twinning is common.

Magnetite is very abundant, both in regular crystals and in skeleton forms in the glassy base. In the latter, as in the case of the augite in the pitchstones of Arran[1], the crystallization of the magnetite has resulted in a sort of halo being formed round the crystals,—the latter having in the act of crystallization drawn the colouring matter out of the base, leaving a comparatively colourless glass in their immediate vicinity.

No. 3.—A dark-grey, almost black, compact rock. Sp. G. 2·83.

M.—This slice consists of a profusion of augite, felspat, and magnetite crystals, scattered about in a glassy base.

The magnetite crystals are of good size, and are fairly well formed. The felspar and augite crystals are of two sizes; in the case of both minerals the majority are of small size (the augites being very minute); whilst here and there are others of comparatively large size. The majority of the felspar prisms are distinctly triclinic. Many of the augites are twinned.

Stellate groups of felspar, similar to those described in my paper on the Darang traps[2], are to be met with in all the Bombay slices. One of them from this specimen is shown in fig. 3, plate II, and another from No. 8 is given in fig. 10, plate II. The latter, which is quite accurately drawn, looks like a cross seen in part profile.

In my paper on the Darang traps I noted how crystals are often cramped at the time of their formation by adjoining crystals. In fig. 4, plate II, I have sketched a twinned augite which has attempted to crystallize in the midst of a perfect barricade of felspar prisms, and its outward symmetry of form has consequently suffered considerably. In such cases, however, though the external shape is deformed, the plane of twinning almost invariably exhibits a rigid straight line, and the internal symmetry, on which the optical properties of the mineral depends, sustains no injury.

In J. D. Danas' Manual of Mineralogy (1873), p. 152, augite crystals are said to be "usually stout and thick, and none have the slender bladed form common with hornblende." In lavas, however, as seen under the microscope, augite crystals sometimes take the form of acicular microliths, and not unfrequently assume the form of elongated prisms. A prism of this character occurs in the slice under consideration, and is represented in fig. 5, plate II.; (*a*) (*d*) is a long prism of augite which has grown up side by side with one of triclinic felspar. From (*c*) to (*d*) the augite is twinned, the twinning plane running with the length of the prism From (*c*) to (*a*) the prism is made up of a crystal not in optical continuity with either of the twins below it. The augite in the course of its formation has enclosed the ends of small felspar prisms, which may be seen sticking, like parasites, into its side. The adjoining felspar prism appears to have grown tranquilly by the side of the augite up to (*b*), when the supply of felspathic material appears to have been less plentiful than that of the constituents of the augite and magnetite (three crystals of which are indicated at this point), and it

[1] Allport. Geological Magazine, Vol. IX, p. 2.
[2] *Supra*, Vol. XV, p. 155.

symmetry was greatly marred by the intervention of crystals of augite and magnetite (*b*). The ill-shaped felspar at the top (see sketch) is no doubt a portion, or what ought to have been a portion, of the prism seen below. The molecules of felspathic matter did their best, I take it, to keep the alignment of the felspar prism, and they are in optical continuity with it, but the augite and magnetite crystals got in the way, and the shape of the felspar prism was marred.

This, and the previously noted illustrations, will, I think, enable us to understand how the external symmetry, and the regular development of crystals in an igneous rock, are seriously interfered with by the contemporaneous formation of other minerals in close proximity to them, or by the presence and pressure of previously formed crystals.

No. 4.—A dark-grey compact rock. Sp. G. 2·82.

M.—The felspar and augite crystals are set in a glassy base, which is sufficiently abundant to entitle the rock to be classed as a magma basalt. The base is, for the most part, of light vandyke-brown colour, but is here and there altered to a substance olive-green in transmitted light. The base is crowded with microliths of magnetite in its rod-like form; it occurs also in large and rather well-shaped crystals and as a fringe round augite.

Almost all the felspar is visibly triclinic, and radiating groups are common.

Augite is very abundant, and very fresh, but its outward shape is rarely good and never perfect. Twinning is common, and the intersection of the prismatic cleavage lines is sometimes well seen.

In fig. 2, plate I, I have given a representation of a portion of this slice. Some of the felspar crystals therein figured present sharp and characteristic outlines; others again are very irregular. On the right hand of the illustration, two augite crystals are seen embracing two curiously shaped crystals of felspar. To the left also a large block, formed of a congeries of shapeless augite crystals, has more or less enclosed a radiating group of very irregularly shaped masses of felspar.[1] The partial enclosure of felspar by augite is very common in these slices, especially in the one under consideration. This, and the enclosure of augite by felspar noted in connection with slice No. 1, seems to indicate that the lava was at first in a very fluid state, in which free molecular action was possible; but that it cooled with such rapidity that the minerals were unable to disengage themselves from each other, and their crystallization was arrested before the symmetry of their external form was complete. Small peculiarities of structure of this kind are, I think, of value. The volcanic origin of the Bombay basalts being well known, structural characters observed in them may aid us to interpret rocks of more doubtful character in other regions.

Professor Geikie, in his paper on the Carboniferous Volcanic Rocks of the Basin of the Firth of Forth,[2] has described similar instances of felspar prisms

[1] Some of these seem to approach those "*complex fan-shaped brushes*" which Dr. Sorby describes as forming the terminations of felspar prisms in artificially melted rocks, and which he met with in a natural rock from a dyke near Beaumaris. Opening address, Geology Section of the British Association, 1880.

[2] Transactions, Roy. Soc., Edinburgh, Vol. XXIX, p. 437.

"shooting" through crystals of augite, and severing the augite into two parts in such a way that "not uncommonly it might be supposed to have been penetrated across its figure by intrusive prisms of felspar;" an appearance which Professor Geikie attributes to augite having "formed round and enclosed the already completed net-work of triclinic felspar prisms."

These partial enclosures of the one mineral by the other are described as occurring in the rocks which he classes as diabases and dolerites. The latter term he proposes to restrict to intrusive sheets and dykes which consolidated beneath the ground, retaining the word 'basalt' for interbedded augitic lavas which consolidated at the surface.

It is to be noted, however, that a glassy base does not appear to be entirely absent from either Professor Geikie's diabases or dolerites; and although I do not intend to infer from the preceding remarks that the intersection of small or moderate-sized crystals of augite by prisms of felspar, or of felspar prisms by augite, is an exclusive characteristic of rocks which have consolidated at the surface of the earth's crust; or that it would enable us to distinguish the latter from intrusive sheets or dykes; still, it is a structural peculiarity of basic volcanic rocks which is worth noting, and it may help us to distinguish basic lavas from basic plutonic rocks. Acid igneous rocks have characteristic features of their own.

The slice under consideration is of larger grain than any of the preceding ones.

No. 5.—A dark-grey compact rock. Sp. G. 2·83.

M.—This is a very fine-grained rock, and so closely resembles those first described that a detailed account of it is not necessary. The magnetite is well formed. The augite is for the most part very small, and twinning is common in the larger crystals.

At fig. 6, plate II, I have sketched an illustration of the way the formation of minerals went on side by side, in these Bombay basalts, at almost the same time. The illustration represents a crystal of magnetite and two crystals of augite. The growth of the lower augite and that of the magnetite appears to have gone on side by side, and, at first, at very much the same pace. The magnetite then gained on the augite and finally partially surrounded it. The formation of the second augite then began and went on so rapidly that it enclosed a portion of the magnetite in its embrace.

No. 6.—A perfectly compact dark-grey rock with a dull green tint in it. It weathers brown. Sp. G. 2·80.

M.—This is a fine-grained magma basalt. The base consists of a brown glass, here and there converted into a green amorphous substance. Augite crystals are abundant in this slice. Most of them are very minute, and, in polarised light with crossed nicols, they stand out from the black background like stars on a clear night. Some are of fairly large size. Twinning is common, and a few of the augites are well shaped.

Felspar is abundant and is chiefly in small prisms. Most of it gives decided evidence of belonging to the triclinic system.

Magnetite is for the most part well shaped and of good size, but it is also to be seen in elongated stalk-like microliths in the glassy base.

Fig. 7, plate II, is an illustration taken from this slice showing the way minerals, in the process of crystallization, catch up, enclose, and become entangled with other minerals. An augite crystal is there seen to have enclosed several crystals of magnetite, and to have partially surrounded crystals of triclinic felspar; whilst other crystals of magnetite have formed on it.

The microscope enables one to understand how it is that the chemical analysis of minerals often yields such divergent results. Fig. 7, will, I think, suggest the explanation of how this takes place.

No. 7.—A compact greenish-grey rock. Sp. G. 2·85.

M.—The grain is larger than that of the preceding slices. Augite is abundant. Much of the felspar exhibits the twinning peculiar to triclinic felspar, and is in characteristic prisms. Felspar also occurs in large crystals and in shapeless masses, some of which are certainly sanidine.

The glassy base is of green colour. Here and there minute portions of it have been converted into delessite, and the whole of it is more or less changed. The rock is passing into the condition of the Darang traps (*l. c.*). In these slices, however, the glassy base can still be distinctly recognised as such. Very little magnetite is left in the rock.

At fig. 3, plate I, I have given a sketch of a portion of this slice. The very dark portion is the glassy base. The less dark portion is augite, and the white is felspar.

At fig. 9, plate II, I have sketched a group of augite crystals in polarised light under crossed nicols. It is impossible, in simple black and white, to indicate the various colours in which the crystals polarise; but the different shades of black will, perhaps, suffice to show the want of optical continuity between the different members of the group. The two small crystals at the upper left hand are seen to be twinned, the twinning plane being a sharp straight line, and the two halves of each twin polarising in complimentary colours. The others are crystals of different sizes and of very irregular shape. The various crystals of which this and similar groups are composed, began to crystallize, apparently, much about the same time from independent centres, and from want of space interfered with each other's growth and development. One micro-augite is enclosed in a large crystal, whilst another augite contains a gas bubble.

The group appears to have been rapidly formed, for along the upper margin a tongue of the glassy base (*a*) is partially enclosed in it.

I have depicted another characteristic group in fig. 8, plate II, taken from slice No. 10. One augite crystal, at the right hand, is seen to be nearly surrounded by a larger crystal of the same mineral. The shapes of all the members of the group are very irregular, and they have evidently interfered seriously with each other's development. The finishing off of the group has been hurried in its last stages, as along the outer margin a zone of cavities is to be seen,—a not

uncommon feature in the augite of volcanic rocks. These cavities, the irregular shapes of the crystals, and the confused association of imperfectly formed augites, are, I think, indications of the rapidity with which the rock cooled.

The large felspar crystals are not at all homogeneous in their internal structure, and they enclose irregular-shaped augite crystals and patches of viridite.

No. 8.—*A greenish compact rock.* Sp. G. 2·4.

M.—This slice very much resembles the last. The glassy base has been converted into a greenish substance which contains in it minute embryonic crystals of epidote. Alteration has been set up in the felspars. Magnetite is not abundant, and is mostly in skeleton forms.

No. 9.—*A greenish-grey compact rock.* Sp. G. 2·85.

M.—In this slice augite is very abundant. The glassy base is still recognisable, but it has passed into an alteration product, olive green in transmitted light, which is in part, at any rate, delessite. A radiating structure is often apparent in it, and all of it is feebly dichroic when the polariser alone is used.

This slice contains a good many sanidine prisms exhibiting the simple twinning of the Carlsbad type, but they are quite subordinate to the plagioclase.

In one case water has clearly gained access to the rock, and a thin undulating ring of quartz has been left behind to mark its passage.

Augite crystals often partially enclose crystals of felspars, and felspars occasionally enclose fragments of the glassy base.

No. 10.—*A grey compact rock.* Sp. G. 2·81.

M.—The glassy base is still to be seen here and there, but in most cases it has been replaced by delessite, and in a few cases by chalcedony. It gives clear evidence of the invasion of water. The latter has often left castellated watermarks behind it, and has partially rounded the margins of the channels through which it flowed, so that in some cases these altered portions of the base have the appearance of amygdules plugging amygdaloidal cavities. I think that the results above described may be accounted for on the supposition that the uncrystallized glassy base yielded more readily to the solvent powers of heated water than the minerals that had crystallized out of it.

It is important to note the tendency, here evidenced, of acid water passing through a rock to excavate *rounded* cavities; the removal of olivine and leucite, and the rounding of the edges of the matrix in which they were buried, might lead to the formation of a pseudo-amygdaloid, and prevent the secondary minerals, substituted for olivine and leucite, being recognised as pseudomorphs of those minerals.

The felspar is more or less altered, but the augite is quite fresh. The slice contains some prisms of sanidine which exhibit characteristic Carlsbad twinning.

No. 11.—*A greenish-grey compact rock.* Sp. G. 2·81

M.—This slice closely resembles the last. The magnetite or titaniferous iron is a good deal decomposed, and much of it has passed into leucoxene. A study of these slices confirms the view taken of the origin of the opaque white

material formed in connection with the Darang basalts. The white opacity diffused in a nebulous way through the latter is, I think, due in many cases, not to the decomposition of large regular crystals of ilmenite, but to the minute dendritic forms of iron disseminated through the base.

This rock generally is passing into a stage of alteration like that described in the traps of Darang (*l.c.*)

Conclusion.

I have not detected olivine in any of these slices either fresh or in an altered condition.

Olivine, though a very characteristic mineral, usually present in basalts, does not appear to be universally so abundant as to be invariably visible in every thin slice made for microscopic examination.

Forchhammer states that it does not occur at all in the basaltic rocks of the Faroe Islands;[1] whilst Professor Geikie, in his paper on the microscopic characters of the basalts of the Firth of Forth,[2] notes that it "varies much in quantity;" and though it is "usually discernible in every thin slice," in some basalts it appears only in occasional "rare and small pieces." Zirkel notes (Microscopical Petrography of the Fortieth Parallel, p. 219) that in rocks "closely allied" to the "proper or genuine felspar (i.e., plagioclase) basalts," and which he classes as a sub-division of the basalts, olivine is generally wanting. In some of the Deccan traps from other localities, specimens of which the Superintendent of the Geological Survey of India has kindly allowed me to see, it is very abundant. Olivine may possibly not be altogether absent from the Bombay lavas; but, if present, it must be sparsely disseminated through them.

In view of the absence, or sparseness, of olivine, the question arises whether these rocks should be classed as basalts at all. In mineral composition they approximate closely to the quartzless-augite-andesites, in which olivine is rarely met with.[3]

The specific gravity of andesites ranges from 2·70 to 2·85; whilst the Bombay lavas, judging from the specimens now described, range from 2·80 to 2·85. In view, therefore, of the absence of olivine, a good case might be made out for classing the Bombay rocks with augite-andesites rather than with basalts.

But, on the whole, it will, I think, be better to retain the name by which the Bombay rocks have hitherto been known, and to continue to call them basalts; for I think it will conduce to clearness and simplicity if we restrict the term 'andesite' to the lava form of diorite and retain the words 'basalt' and 'dolerite' for basic augitic lavas. The term 'augite-andesite' seems a suitable one for intermediate forms between the two in which augite and hornblende are both present; and I prefer not to use it for the Bombay rocks because they contain no trace of the latter mineral.

As the Bombay basalts are very typical volcanic rocks, it may be useful, and may aid us to determine more doubtful rocks in other localities, to sum up the indications they afford of being superficial lava streams.

[1] Bischof's Chemical Geology, II, p. 356.
[2] *Loc. cit.*, p. 506.
[3] Rutley's Study of Rocks, p. 236.

The following points, I think, afford evidence of rapid cooling, though some of them are more cogent than others :—

1. The presence of a glassy base.
2. Skeleton, dendritic, and rod-like forms, of magnetite and (?) ilmenite.
3. The presence of glass enclosures, and gas bubbles, in augite and felspar crystals.[1]
4. The abundance of felspar prisms of small size, the longer axis of which usually points in all directions.[2]
5. The abundance of granular[3] and minute crystals of augite.
6. Clusters of irregular-shaped augite crystals.
7. Imperfectly-formed and feathery felspar crystals.[4]
8. The penetration of augite by felspar and of felspar by augite.

EXPLANATION OF PLATES.

PLATE I.

Figs. 1, 2, and 3.—Thin slices of Bombay basalts as seen under the microscope.

PLATE II.

Fig. 1.—Partial enclosure of felspar by augite.
Fig. 2.—Partial enclosure of augite by felspar.
Fig. 3.—Stellate prisms of felspar.
Fig. 4.—A twinned augite and felspar prism.
Fig. 5.—Augite and felspar prisms formed side by side.
Fig. 6.—Augite and magnetite formed at nearly the same time.
Fig. 7.—Augite enclosing magnetite and felspar.
Figs. 8 and 9.—Irregular-shaped clusters of augite crystals.
Fig. 10.—Another stellate form of felspar.

[1] Dr. Sorby, Ann. Address, Q. J. G. S. XXXVI, 53.

[2] Professor Geikie, in the paper already quoted, states that intrusive dolerite "along the line of contact with a sandstone or other granular rock" "becomes exceedingly close-grained," and the felspar prisms "tend to range themselves parallel with the surface of the sandstone."

[3] Professor Geikie, in the paper already quoted, writes of the volcanic rocks of the Firth of Forth :—"There is one distinctive feature between the mode of occurrence of the augite in the 'dolerites and in the interbedded anamesites and basalts which I have found to hold good with 'few exceptions. While in the intrusive sheets the augite occurs either in well-marked crystals or 'in large crystalline irregularly-shaped portions, in the superficial lava-beds it is commonly present 'in abundant small granules and in sparse definite crystals."

[4] See Dr. Sorby's opening address, Geology section of the British Association, 1880.

Fig. 1 × 60

Fig. 2 × 85

Fig. 3 × 85

Reproduced in heliogravure from the original drawings at the Surveyor Generals Office, Calcutta.
January, 1883.

Fig: 1

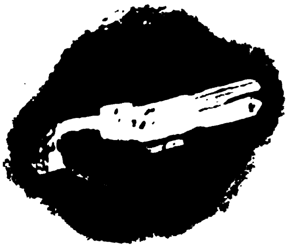


Fig: 2

Fig: 3

Fig: 4

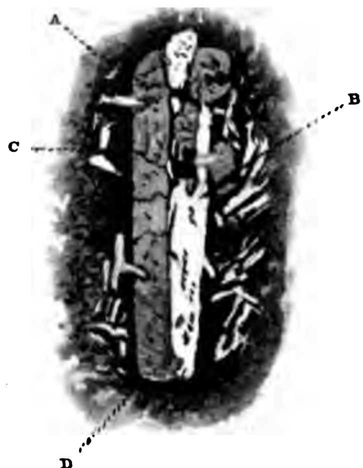


Fig: 5

Fig: 6

Fig: 7

Fig: 8

Fig: 9

Fig: 10.

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January 24th, 1883.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1883. [May.

Synopsis of the Fossil Vertebrata *of* India, *by* R. Lydekker, B.A., F.G.S., F.Z.S.

INTRODUCTORY.

In the "Journal of the Asiatic Society of Bengal" for the year 1880 there appeared a paper by the present author, under the title of a "Sketch of the History of the Fossil Vertebrata of India," in which every species of fossil vertebrate animal then discovered in India was recorded, while there was also given a short summary of the labours of those palæontologists who had written on the Indian Fossil Vertebrata. Since the date of publication of that paper a great increase in our knowledge of the subject has been obtained, and it has accordingly been thought advisable to republish the substance of that paper, with such additions and alterations as are necessary to bring it up to the present state of our knowledge. In many instances these alterations have been so extensive as to have made it necessary to totally re-write a great portion of the original paper. It has been thought better to omit the introductory portion, in which the names of the chief workers in this field of enquiry are recorded, as there is no essential alteration to be made regarding them. Some introductory observations on the general relations of the Indian fossil vertebrates have likewise been omitted, as well as all the references. The record of the local distribution of species, and the places where the more remarkable specimens are preserved, form a new feature in this memoir.

The plan of the original paper has been in the main strictly adhered to; this consists in taking each of the classes of the vertebrata and recording their geological distribution, from the oldest to the present time. At the end a systematic synopsis of all the known forms is given, arranged according to their geological distribution; and also an alphabetical list of the species.

CLASS I.—PISCES.

Carboniferous.—The earliest fishes of which there is any record are known merely by a few specimens of teeth and dorsal spines obtained in the palæozoic rocks of the Salt-range in the Panjáb. The beds from which these remains were obtained are termed the "Productus-Limestone," and are considered to correspond roughly to the carboniferous of Europe. Among these fishes there is a new

genus of ganoid described, upon the evidence of a single tooth, under the name of *Sigmodus dubius*; this tooth is of an elongated conical form, much resembling the teeth of certain Saurians. Of the *Cochliodontidæ*, here provisionally referred to the Ganoidei, there are two genera, each represented by a single species, namely, *Pœcilodus paradoxus* and *Psephodus indicus*; the tooth of the former is of the flattened cestraciont type. Of the Elasmobranchii, five genera have been named, some from the evidence of teeth, and others from spines; but, in view of certain modern discoveries, it is not impossible that in some cases distinct genera have been formed from the different remains of the same animal. Of these the new genus *Helodopsis*, allied to the European *Helodus*, has been formed for the reception of two teeth, which have been referred to distinct species under the respective names of *H. elongata* and *H. abbreviata*. A fragmental tooth, too imperfect for specific determination, has been referred to the common European carboniferous genus *Psammodus*. A fourth tooth, under the name of *P. indicus*, is referred to the European genus *Petalorhyncus*, which is very doubtfully separated from *Petalodus*. Of the spines, three specimens are referred to the genus *Xystracanthus*, of the carboniferous of America, under the names of *X. gracilis*, *X. major*, and *X. minor*; the possibility of these specimens belonging to some species of *Helodopsis* is, however, suggested. A fourth spine is referred to a new genus, under the name of *Thaumatacanthus blanfordi*. As far as the evidence of these fishes goes, it is apparent that sharks with crushing teeth were the dominant forms in the Indian carboniferous seas, as well as in those of Europe and America. All the specimens noticed above are in the collection of the Indian Museum.

From the same rocks there have been obtained teeth of two species of the elasmobranch genus *Acrodus*, to one of which the name *A. flemingi* has been applied. Other small teeth have been doubtfully referred to the ganoid genus *Saurichthys*, with the name of *S. (?) indicus*.

Trias-jura.—In the upper portion of the great Gondwána system, probably corresponding as a whole to the trias and jura, remains of fishes have been found in some abundance, the determined forms belonging to freshwater ganoids. In the Maleri group[1] of this system, the fauna of which shows a rhæto-triassic facies, three spines of the genus *Ceratodus* have been determined, and respectively named *C. hislopianus*, *C. hunterianus*, and *C. virapa*. The latter is considered to be closely allied to *C. polymorphus* of the rhætic of Bristol. At the present day the genus inhabits the rivers of Queensland, and in Europe is found fossil from the Keuper to the Jura. The specimens of the Maleri teeth are in the Indian Museum. From the Kota group, sometimes classed with the Maleri group, but showing a more distinctly liassic series of fossils, nine species of ganoids have been determined, belonging to the genera *Dapedius*, *Lepidotus*, and *Tetragonolepis*, all of which occur in the secondary strata of Europe, where they range from the lias to the eocene, *Lepidotus* being especially characteristic of the wealden. The majority of the specimens on which these species are founded are, it is believed, in the collection of the Geological Society, but there are a few in the Indian Museum;

[1] I follow the Director General of the Geological Survey of Great Britain and Ireland in continuing to use the term 'group' as subordinate to the terms 'system' and 'series.'—See Geikie: "Text-Book of Geology," 1882, p. 635.

in many cases they comprise nearly perfect fish. Bones, apparently of fishes, have been obtained from the trias of Tibet, but are too imperfect for determination.

Cretaceous.—A few remains of fishes have been obtained from the middle cretaceous Lameta group, but are not determined, though it has been suggested that some of them may belong to the genus *Sphyrænodus*, of the eocene and miocene of Europe. From the middle and upper cretaceous Trichinopoli series, seventeen species of Elasmobranchi have been described, belonging to the genera *Corax, Enchodus, Lamna, Odontaspis, Otodus, Oxychina, Ptychodus*, and *Sphærodus*, and one ganoid, doubtfully referred to *Pycnodus*; all these genera occur in the cretaceous of Europe, of which period some are characteristic. Two of the Indian species, *viz.*, *Corax pristodontus* and *Ptychodus latissimus*, are common to the cretaceous of Europe. Most of these species are founded on the evidence of teeth, some of which are in the Indian Museum and others in the collection of the Geological Society of London.

Eocene.—From the eocene of the Andaman Islands and Rámri Island on the Arakán coast, there have been obtained two teeth of a large *Diodon*, named *D. foleyi*; from the occurrence of *D. hystrix* off these coasts at the present time, it may be assumed that the genus has lived there since the eocene. Remains of a large species of this genus have been obtained from the miocene of Malta. Undetermined cycloid scales have been obtained from the eocene of Thyetmyo in Burma. From the eocene of the Panjáb there are other undetermined scales, and the dental plate of a species of eagle-ray,—*Myliobatis*,—a genus very common in the eocene of Europe, and widely distributed at the present day. From the neighbourhood of Kohát, in the Panjáb, from strata of eocene or lower miocene age, a single incisor of a sparoid fish, named *Capidotus indicus*, has been obtained. The genus was previously known only from the miocene of Vienna and Silesia, and is allied to the living *Sargus*. All the above specimens of teeth are in the collection of the Indian Museum.

Pliocene.—From the Siwalik series numerous species of fishes have been obtained, though severa lhave not been determined. Among the siluroids, we have a large skull in the Indian Museum (originally referred to a gigantic batrachian) belonging to the living species *Bagarias yarrelli*, of the larger Indian and Burman rivers. The British Museum has the anterior portion of the skull of a siluroid (labelled *Pimelodus*), belonging probably to a smaller species of the same genus; and a smaller but nearly complete skull in the same collection belongs probably to this species. The survival of a pliocene fish to the present day is a fact of much interest. The genus would seem to have been widely distributed in eocene times throughout the East, as a species has been described from the tertiaries of Sumatra under the name of *B. gigas*. The posterior half of the skull of a gigantic siluroid in the British Museum indicates another genus of this group. Palatal teeth of a third form of siluroid, from the Panjáb and Sind, and now in the Indian Museum, probably belong to the genus *Arius*, now inhabiting the rivers of India. Among the elasmobranchi a few teeth indicate a species of Siwalik *Lamna*, while a single tooth in the Indian Museum from Burma belonged to a small species of *Carcharodon* or *Carcharias*. Large squaline vertebræ, now in the Indian Museum, have been obtained from the Siwaliks of Perim Island.

From the tertiaries, or post-tertiaries, of the Káshmír valley a few fish-scales have been obtained.

CLASS II.—AMPHIBIA.

Trias-jura.—The oldest-known Indian amphibian is represented by a skull and part of the vertebral column, from the Bijori group of the Gondwánas, of a large species. This fine specimen belonged to the Asiatic Society of Bengal, and was sent to England for description about 18 years ago, since which time it has lain unnoticed. It has recently been recovered, and the writer hopes subsequently to give a description of it. The skull is of a triangular shape, and has been referred to *Archegosaurus* and *Labyrinthodon.* In its restricted sense, no skull is known of the latter genus, and it is quite possible that the Indian specimen may belong to *Mastodonsaurus* or to some other genus. Provisionally, it is convenient to refer to it as an *Archegosaurus* (see Note, p. 93).

From the Panchet group of the Gondwánas three genera of slender-jawed labyrinthodonts, allied to those of the European trias, are known. The first of these, *Pachygonia*, has only the one species *P. incurvata*, and is known by the greater part of the mandible, and a fragment of the skull. The marking of the former is like that of *Mastodonsaurus.* The second genus, *Gonioglyptus*, has two species, the smaller known as *G. longirostris* and the larger as *G. huxleyi*; it is considered to be closely allied to *Trematosaurus* of the bunter-sandstone of Germany. The third genus is known only by a single fragment of the mandible, to which the name *Glyptognathus fragilis* has been applied. These three genera are peculiar to India, and all their remains are exhibited in the Indian Museum; the two former belong to the group Euglypta.

From the Mángli beds of the Gondwánas, another peculiar genus of labyrinthodont has been obtained, and is represented by a single skull in the collection of the Geological Society, to which the name *Brachyops laticeps* has been applied. The genus is allied to *Rhinosaurus* from the jurassic of Europe, to *Micropholis* of the trias of Africa, and to *Bothriceps* of the trias of Australia, and with them constitutes the group Brachyopina.

From the Maleri group fragmentary jaws of a species of *Pachygonia*, probably the same as the Panchet form, have been obtained, as well as simple biconcave vertebræ of considerable size, probably belonging to a labyrinthodont; these specimens are in the Indian Museum.

Tertiary.—No amphibian remains have hitherto been obtained between the trias-jura and the tertiaries. In the lower series of the latter at Bombay there occur numerous remains of a small frog, belonging to the genus *Oxyglossus*, now living in China, Siam, and possibly India; the fossil species is extinct, and is known as *O. pusillus*: remains of a larger, but undetermined, frog are also indicated.

CLASS III.—REPTILIA.

Trias-jura.—The oldest reptiles hitherto found in India belong to the orders Dinosauria and Dicynodontia, and occur near Rániganj in lower Bengal, in the Panchet group of the Gondwanas, probably of triassic age. The remains

of a species of *Dicynodon*, belonging to the sub-genus *Ptychognathus*, are of comparatively common occurrence in the coarse Panchet sandstone, and have been described as *D. orientalis*. Other remains seem to indicate a second and larger species of the genus. This order of reptiles seems to be characteristic of the trias of India, Russia, and Africa, and to have attained its fullest development in the latter country. The remains of the Indian forms all occur over a very small area in one thin seam of the Panchets. The Dinosaur has been named *Ankistrodon indicus*, and is the sole representative of the genus; it is known merely by two minute compressed and trenchant teeth with serrated edges, like those of *Megalosaurus*, implanted in distinct sockets. The above specimens are in the Indian Museum. The Maleri group of the same system has yielded numerous, though much broken, remains of a large crocodilian, constituting the still undescribed genus *Parasuchus*, and bearing the manuscript specific name of *hislopi*, after the late Rev. Mr. Hislop, the discoverer of the vertebrate fossils of the Maleri group. This crocodile belonged to the amphicœlian division of the order, and seems to have been closely allied to *Belodon* and *Stagonolepis* of the trias of Europe, the three genera forming a group characterised by the non-union of the pterygoids behind the palatines. The scutes referred to *Parasuchus* differ from those of living crocodiles by their sculpture consisting of ridges and furrows radiating from a sub-central point, instead of isolated irregular pits. From the Denwá group of the same system a single scale of a gigantic crocodilian, probably belonging to the above genus, has been obtained. The Tiki beds in South Rewá, which are not improbably the equivalent of the Panchet group, have yielded other crocodilian remains, agreeing in the structure of the scales with *Parasuchus*, but distinguished by a totally different form of barioccipital, whence it is inferred that they probably belong to a distinct genus. In addition to the above, the Maleri and South Rewá rocks have yielded remains of a large species of the lacertian genus *Hyperodapedon*, originally described from the English trias. The Indian species, *H. huxleyi*, differs from the European, *H. granti*, by the greater number of the palatal teeth, and the presence of some additional teeth on the outer surface of the mandible; its length has been roughly estimated at 16 feet. The genus is closely allied to the living *Hatteria* of New Zealand, and has been supposed to have an affinity to *Rhynchosaurus* of the trias of Europe. From the Chári group of the jura of Kach there has been obtained a single crocodilian vertebra, not improbably belonging to *Parasuchus*; and from the Umia group of the same, a fragment of the mandible of a *Plesiosaurus*, described as *P. indicus*; the affinities of this form cannot be fully determined from the specimen.

The whole of the remains from the trias-jura, mentioned above, are in the collection of the Indian Museum.

Cretaceous.—From the Trichinopoli group (upper cretaceous), and probably from the Lameta group (middle cretaceous), there have been obtained a few teeth of a species of *Megalosaurus*, a genus whose range in Europe extends from the jurassic to the wealden; the one tooth of the Indian form now forthcoming is in the Indian Museum. From the Lameta series there have also been obtained the remains of another genus of gigantic dinosaur, to which the name *Titano-*

saurus has been assigned. This genus is allied to *Pelorosaurus* of the English wealden, and to *Oetiosaurus* of the jurassic, and was a long-tailed terrestrial form. The genus was represented by two species,—*T. indicus* and *T. blanfordi;* the former characterised by the centre of the caudal vertebræ being compressed, while in the latter they are sub-cylindrical. Numerous vertebræ, chiefly caudal, and a huge femur, nearly 4 feet in length, are preserved in the Indian Museum, and there is a cast of one of the former, belonging to *T. indicus*, in the British Museum. A few bones, in the former collection, indicate a smaller undetermined reptile from the Lametas.

The Chelonia are known in the cretaceous merely by some broken plates, in the collection of the Indian Museum, obtained from the Lametas, from the infra-trappeans of Rájamahendri (Rajamundry), and from the upper cretaceous of Sind.

The Crocodilia of the cretaceous are known only by one amphicœlian species, apparently allied to *Suchosaurus* of the English wealden, of which some vertebræ have been obtained from the upper cretaceous of Sind, and are now in the Indian Museum.

A large species of *Ichthyosaurus*, named *I. indicus*, is known solely by a few vertebræ obtained from the middle cretaceous of Trichinopoli, and now in the Indian Museum; the range of the genus in Europe is from the lias to the chalk.

Eocene.—The only specifically determined eocene reptile has been referred to the genus *Hydraspis*, under the name *H. leithi*. The specimen on which this determination rests is a carapace from the inter-trappeans of Bombay. The genus *Hydraspis* belongs to the *Emydidæ*, and is now confined to tropical America. From the nummulitics of the Panjáb numerous fragmentary remains of crocodilians have been obtained, but in too imperfect condition for determination.

Pliocene[1].—Many of the Siwalik chelonians in the British and Indian Museums are still undescribed, and the following list must, therefore, be considered imperfect. Of the Crocodilia, a species from the Sub-Himalaya and Perim Island has been identified with the living Indian *Crocodilus palustris* (*bombifrons*), remains from Burma and Sind probably belonging to the same species. Of the genus *Gharialis* (*Leptorhynchus*), a species from the Sub-Himalaya, Burma, Sind, and Perim Island is identical with *Gharialis gangeticus* of the Ganges and Jamna. A second species from the Sub-Himalaya, with slender teeth, has been named *G. leptodus;* and a third, of gigantic dimensions, and with shorter and stouter jaws and teeth, *G. crassidens;* the latter has been obtained from the Sub-Himalaya, Burma, and Sind. Remains of the above species are preserved both in the British and Indian Museums.

Of the order Lacertilia only one species of *Varanus* is known, and named *V. sivalensis:* this determination rests on the evidence of the distal extremity of a humerus, from the Sub-Himalaya, in the British Museum. The genus *Varanus*

[1] In this memoir the fossiliferous Siwaliks of Sind (lower Manchhars) are termed earlier pliocene, and those of the Sub-Himalaya and other parts of India higher pliocene,—the possibility of some of the Sind beds being of miocene age being still kept in view. The terms earlier and higher pliocene are intended merely to indicate that the one is older than the other, and not to indicate their correlation with the divisions of the European pliocene.

is now of common occurrence, and has probably existed since the oligocene, as the so-called *Palæovaranus* of the Quercy phosphorites is probably the same.

The Ophidia are known only by some vertebræ from the Panjáb and Sind, belonging to the genus *Python*, and not distinguishable from those of the living Indian *P. molurus;* these specimens are in the Indian Museum. A species of python (*P. cadurcensis*) from the Quercy phosphorites seems to have very closely resembled *P. molurus*.

The Chelonia are well represented, and comprise among other land tortoises the gigantic *Colossochelys atlas* from the Sub-Himalaya and Burma. This form is stated to be mainly distinguished from *Testudo* by the thickening of the episternal portion of the plastron, but it is doubtful if this character is of generic value, and the species should probably be referred to the latter genus. The length of the restored carapace in the British Museum is 12 feet 3 inches, and the entire animal, with the head and tail extended, is considered to have attained the length of 22 feet. In addition to this gigantic animal there is good evidence of the existence of other large tortoises, as the Indian Museum possesses several specimens of the ankylosed episternals of at least two species of large tortoises. These bones are as thick, but not as long, as those of *Colossochelys*, and their extremities are shorter, but more divergent; they probably belonged to species of *Testudo*, about two-thirds the size of *C. atlas*. A broken episternal indicates a third, but smaller species; while a fourth species of about the same size as the last is represented by three episternals in the Indian Museum, which are not bifurcated at their anterior extremities. A single carapace of a small tortoise in the Indian Museum seems also to belong to the genus *Testudo*. Among the hard-shelled emydine tortoises we have a species of *Bellia*, represented by two carapaces in the Indian Museum, which has been named *B. sivalensis*, and is considered to be closely allied to *B. crassicollis*, now inhabiting Tenasserim, Siam, and Sumatra; the genus is only represented by one other living species, *B. nuchalis* of Java. Another carapace in the Indian Museum, also from the Panjáb, seems to indicate a second Siwalik species of the genus. In the British Museum there are two carapaces of Siwalik land tortoises, with three dorsal ridges, which, although differing considerably in size, evidently belong to the same species, and since the smaller cannot be distinguished from the living *Damonia hamiltoni*, inhabiting Lower Bengal, they may be referred to that species; as is frequently the case, however, the fossil form greatly exceeded the living in size. The larger specimen was named *Emys hamiltonoides* in manuscript. An imperfect carapace from the Panjáb, in the collection of the Indian Museum, seems to belong to the genus *Emys*. A single marginal plate, also in the Indian Museum, has been referred, under the name of *Cautleya annuliger*, to a new genus, said to be distinguished from all other emydine tortoises by the cartilaginous, in place of the osseous, union of the marginals with the adjoining plates. Among the Bataguridæ, some carapaces in the British Museum indicate an animal identical with the living *Pangshura* (*Emys*) *tectum*, now inhabiting Lower Bengal; the fossil form attained a larger size than the recent. A large species of *Batagur* has been obtained in some numbers, but is not specifically determined. A carapace of this genus in the Indian Museum, with a ridge on the vertebral

plates, very probably belongs to a second species. Remains of a large *Trionyx* are likewise not uncommon, but have not yet been specifically determined. A carapace in the British Museum has been identified with the living *Emyda vittata* (*ceylonensis*) of Central and Southern India and Ceylon, and it is probable that numerous other remains of this genus may be referred to the same species.

Pleistocene.—The reptiles of the pleistocene are still very imperfectly known, but it is probable that they all belong to living Indian species. From both the Jamna and Narbada beds specifically indeterminable remains of crocodiles have been obtained. Two complete specimens of the carapace of *Pangshura tectum* from the Narbada are in the Indian Museum, and serve to connect the living with the Siwalik form, and show that the range of the species once extended over the greater part of India. A portion of the plastron of a *Batagur* from the Narbada has been provisionally referred to *B. dhongoka*, now found in the same river. A fragment of the carapace of a *Trionyx*, from the same deposits, probably belonged to *T. gangeticus*, and it is highly probable that a large chelonian cranium in the British Museum, from the same deposits, should be referred to the same species.

General.—The foregoing notes will show that the fossil reptiles are very few in number, and that many are only known by very fragmentary remains. The known mesozoic forms belong entirely to extinct genera; the one known eocene reptile belongs to a genus still living, but now far removed from India; the pliocene forms (with the exception of the doubtful genus, *Colossochelys*) all belong to modern Indian genera, and frequently to existing species, although their range is now frequently restricted to the more southern parts of India; in the pleistocene it is probable that all the forms belong to existing species, which still inhabit the same districts as their fossil ancestors.

Class IV.—AVES.

Pliocene.—Remains of birds have hitherto been found only in the Sub-Himalayan Siwaliks, and in one instance in Sind; their numbers are still very small. Some of these remains are in the British, and the others in the Indian Museum. Among the carinates, a tarso-metatarsus has been considered to belong to a cormorant, and is provisionally referred to the genus *Graculus.* A species of pelican (*Pelecanus cautleyi*), somewhat smaller than the living Indian *P. mitratus*, is indicated by a fragment of the ulna; while another fragment of the same bone has been referred to a second species, under the name of *P. sivalensis*, but there is some doubt whether the generic determination is correct. A gigantic wader has been described, from the evidence of a sternum and tibia, under the name of *Megaloscelornis sivalensis*, and it is possible that the condyles of a humerus from Sind, measuring 2 inches in diameter, may belong to the same genus. A species of adjutant stork, which appears to have had considerable variations in size, has been named *Argala falconeri*. The Ratitæ appear to have been represented by three species, one of which was a true ostrich (*Struthio asiaticus*[1]), and is known by several bones of the leg and foot; and some cervical vertebræ. The second species is an emeu (*Dromæus sivalensis*,) and is indicated

[1] The name *S. palæindicus* occurs in manuscript.

by some toe-bones; while the third, which is not even generically determined, is considered to be a three-toed form, intermediate between the ostrich and the emeu, and is only known by one of the bones of the foot.

CLASS V.—MAMMALIA.

Eocene.—No traces of mammals have yet been detected below the eocene, and there only some very fragmentary bones have been obtained from the Panjáb. The determinable bones consist of the distal portions of the femur and the metatarsus of a perissodactylate animal, allied to, if not identical with, the palæothere and the astragalus of an artiodactylate. The latter was obtained above the nummulitic clays of Fatehjang, and belonged to a (probably) ruminant animal, in which the navicular and cuboid elements of the tarsus were united. These specimens are in the Indian Museum.

Miocene.—The only definitely determined miocene mammal is a rhinoceros from the Gáj beds of Sind, which is apparently a variety of *R. sivalensis*, and has been named *v. gajensis*.

Pliocene.—The primates are known merely by a few fragmentary specimens of upper and lower jaws, with their teeth, and by one bone. The palate of a female, and the upper canine of a male, have been referred to a large anthropoid ape, under the title of *Palæopithecus sivalensis;* the genus seems to be allied to the orang, but is distinguished by the narrower form of the premolars: this specimen is in the Indian Museum. The half of a palate, not improbably belonging to a species of *Semnopithecus*, in the British Museum, has been provisionally named *S. subhimalayanus*. A lower jaw and an astragalus, the former in the British Museum, seem probably to belong to a smaller form of *Semnopithecus*, considered to be distinct from the former species. A species of *Macacus*, larger than *M. rhesus*, is indicated by two fragments of the mandible, in the British Museum; while a second species, smaller than *M. rhesus*, and known as *M. sivalensis*, is represented by two fragments of the maxilla, with teeth, in the Indian Museum.

Among the Carnivora we find a large species of tiger, characterised by its greatly developed sagittal crest, which has accordingly been named *Felis cristata*[1]; this species is represented by three crania (and limb-bones) in the British Museum, to one of which the separate specific name *F. grandicristata* has been applied, but apparently on insufficient grounds. The Indian Museum possesses some limb-bones, and a lower carnassial tooth, which not improbably belong to this species. A smaller species of the genus, about the size of *F. bengalensis*, is indicated by a single ramus of the mandible, in the Indian Museum. The genus *Machairodus* is represented by *M. sivalensis* (*M. falconeri*, Pomel), apparently varying in size from the dimensions of the jaguar to those of the tiger, although it has been proposed to distinguish the larger form under the name of *M. palæindicus*. This species is represented by two broken skulls, and numerous fragments of the jaws in the British Museum, and by the hinder part of a small skull, and part of the mandible in the Indian Museum. The genus *Pseudælurus*, distinguished from *Felis* by the presence of three, or occasionally four,

[1] The manuscript name, *F. palæotigris*, exists.

in place of two lower premolars[1] (although the ante-penultimate premolar is occasionally present as an abnormality in *Felis*), is known by a ramus of the mandible, in the Indian Museum, named *P. sivalensis;* the species was about equal in size to a small leopard. Among the civet-like animals we have a species of *Viverra*, said to be closely allied to the living civet, and represented by two skulls in the British Museum, to which the name *Viverra bakeri* has been applied. *Ictitherium* is represented by *I. sivalense*, of which the two rami of one mandible, a broken ramus, without teeth, of another, and a canine tooth are known, all of which are in the Indian Museum, and came from the Panjáb. The hyænas are represented by *Hyæna sivalensis*, said to present relationship both to the Indian *H. striata* and to the African and European *H. crocuta*, of which there are numerous specimens of the skull and mandible in the British and Indian Museums. It has been proposed to separate some of these specimens under the name of *H. felina*, a so-called species said to be characterised by the absence of the first upper premolar, and by the minute size of the last upper true molar; a large series of specimens shows, however, a great variety in these respects. Remains of a species of *Hyæna* have been described from the pliocene of China, and referred to a distinct species. The dogs are represented by *Canis cautleyi*, and *C. curvipalatus;* the former closely allied to the wolf: portions of the skulls of these species are in the British Museum, and a specifically undetermined palate in the British Museum. The genus *Amphicyon*, distinguished from *Canis* by its plantigrade character and by the presence of an additional upper true molar, is represented by *A. palæindicus*, of which the Indian Museum possesses several specimens of the jaws and teeth from Sind and the Panjáb. The bears are represented by the genera *Ursus* and *Hyænarctos:* of the former there is a skull, without teeth, from the Sub-Himalaya, and a canine from the Irawádi, both in the collection of the Indian Museum. Of the latter there are two species, *H. sivalensis* and *H. palæindicus*. *H. sivalensis* has the molars with quadrangular crowns, and is known by a fine skull, the half of a mandible, and some limb-bones, in the British Museum; and by numerous specimens of the teeth and jaws in the Indian Museum; a single upper molar from the newer pliocene of England much resembles the teeth of this species. *H. palæindicus* is known only by a single maxilla in the Indian Museum, and is distinguished by the triangular form of the crowns of the upper molars, which approach those of *Amphicyon*. Of the subursoid carnivores, the genus *Mellivora* (*Ursitaxus*) is represented by *M. sivalensis*, known by a fragment of the mandible from the Panjáb, in the Indian Museum, and apparently very closely allied to the living Indian species; and the genus *Meles* by a single species, of which there is also only a fragment of the mandible contained in the Indian Museum. Of the otters, *Lutra palæindica* has been named from the evidence of a skull and lower jaw in the British Museum; and a second species seems to be indicated by a lower jaw from the Panjáb, in the Indian Museum. *Enhydriodon*, represented by *E. ferox*, is a genus peculiar to the Siwaliks; the only known specimens are two skulls in the British Museum, a part of the maxilla in the Museum of the Royal College of Surgeons, and a mandible. The genus takes its name from its

[1] Occasionally a tubercular true molar is present, and the genus then approaches *Proailurus*.

affinity to the living sea-otter (*Enhydras*). The living genus inhabits the coasts of the North Pacific during winter, and proceeds up the rivers in summer; but it is probable that its fossil ancestor must have been entirely a river-dwelling form.

The Proboscidia are very abundantly represented, species of all the known genera or sub-genera being present. The most specialised genus, *Euelephas*, is represented by *E. hysudricus*, of which the molars are of less complex structure than those of *E. indicus*. *Loxodon* is represented by *L. planifrons*, remarkable for being the only species of true elephant in which premolars are known to have been developed. The genus or sub-genus *Stegodon*, peculiar to South-Eastern Asia, is represented by four species. Of these the molars of *S. ganesa* and *S. insignis* appear to be indistinguishable from one another; the skull of the former, however, of which there is a magnificent specimen in the British Museum, is distinguished by its enormous tusks; while that of the latter, of which there are numerous specimens, by the peculiarly depressed form of the fronto-parietal region. Molars of either *S. insignis* or of the next species, if not of both, have been obtained from strata of probably pliocene age in Japan. The molars of the third species, *S. bombifrons*, are less complex than those of the preceding; its skull has very prominent frontals; remains of this species have been obtained from the pliocene (?) of China, and described under the name of *S. orientalis*. Of the fourth species, *S. clifti*, the skull is unknown, but the molars are still simpler, the intermediate ones bearing only six ridges each; remains of this species have also been obtained from Burma, Japan, and China, a tooth from the latter country having been named *S. sinensis*. Five species of mastodons are also known, three belonging to the tetra-, and two to the tri-lophodont subdivision of the genus. Of the former, *M. latidens* approaches nearest to the stegodons, and, as it has open valleys, and the intermediate molars occasionally carry five ridges, it affords such a complete transition between *S. clifti* and the other mastodons that it seems highly probable that the generic divisions of the elephants and mastodons should be swept away, and the whole of them included under one large genus. The skull of *M. latidens* is unknown; its remains have been obtained from the Irawádi valley, the Sub-Himalaya, Sind, and Perim Island. *M. perimensis* has the molars rather less regular than the last; there is a fine skull in the British Museum, and its remains have been found in the Panjáb and Perim Island. The third tetra-lophodont species, *M. sivalensis*, has the molars with an "alternate" arrangement of the ridges, and occasionally presenting a tendency to a pentalophodont formula; there is a fine skull in the British Museum, and remains of this species have been obtained only from the Sub-Himalaya. The skulls of the two trilophodont species are unknown, and all their remains, which are from the Panjáb, Sind, and Perim Island, are in the Indian Museum [1]. In the first, *M. falconeri*, the valleys of the molars are open, and the symphysis of the lower jaw is short, and sometimes provided with small cylindrical tusks. In the second, *M. pandionis*, the valleys of the molars are obstructed by outlying columns, and the symphysis of the lower jaw is produced into a long trough-like process, which may or may not be furnished with large compressed tusks. Of the genus *Dinotherium* three species are

[1] This is exclusive of the remains of *M. pandionis* from the pleistocene of Madras.

known: the largest of these, *D. indicum*, rivals in size the European *D. giganteum;* there are several specimens of the teeth and jaws in the Indian Museum, and also in the collection of the Bombay Branch of the Royal Asiatic Society; there is also a cervical vertebra, part of the mandible, and an upper molar in the British Museum; remains of this species have been obtained from the Panjáb and Perim Island. The second species, *D. pentapotamiæ*, is of smaller size, and has been obtained from the Panjáb, Kach, and Sind; numerous specimens of the teeth and jaws are exhibited in the Indian Museum. The last species, *D. sindiense*, is only known by two specimens of a part of the mandible, one from Sind and the other, lacking the crowns of the molars, from the Panjáb; both specimens are in the Indian Museum. The mandible in this species is subcylindrical in cross-section, and thereby approaches the mastodons.

Coming to the Ungulata, we find both the perisso-, and the artio-dactylate sections well represented, though the latter are by far the most numerous. Among the former, we have the rhinocoroses represented by three species of true *Rhinoceros:* the first of these was a unicorn form, apparently very closely allied to the living *R. javanicus* (*sondaicus*), which it resembles in the form of its molars and the mandible. Skulls and teeth of this species are contained both in the British and Indian Museums, and its remains have been obtained from the Sub-Himalaya and Sind. The second species, *R. palæindicus*, does not seem to come very near to any living form; this species was also unicorn, and the mandible had two pairs of incisors; the upper molars are intermediate in structure between those of the living Javan and Indian species. Most of the remains of this form are from the Sub-Himalaya, and are in the British Museum. The third species, *R. platyrhinus*, was of huge size, and furnished with two horns; its molars are of the complex type of *R. indicus*, and its mandible has no incisors like the mandibles of the living African species, and the extinct *R. pachygnathus* of Pikermi. Remains of this species have been obtained only from the Sub-Himalaya, and are nearly all in the British Museum, where there is a nearly complete skull. All the above species have high-crowned (hypsodont) molars. It is possible that certain remains from the Bhúgti hills, now in the hands of the writer, may indicate a new species of the genus, with a mandible resembling that part in the existing African species.

Imperfect molars of a species of *Rhinoceros* have been obtained from the pliocene of China, and described as *R. sinensis*. The hornless rhinoceroses are represented by the gigantic *Acerotherium perimense*[1], of which there are a fine skull and numerous teeth and jaws from the Panjáb, in the Indian Museum, and a magnificent palate and some specimens of the mandible, from Perim Island, in the collection of the Bombay Branch of the Royal Asiatic Society; the British Museum also possesses a few specimens of teeth and jaws from Perim Island. The genus *Chalicotherium*, formerly classed among the artiodactylates, but now placed by many among the perissodactylates as a link between the rhinoceroses and the palæotheres, is represented by *C. sivalense*,—a species presenting a peculiarly aborted dentition, and hence referred by some to a distinct genus, under the name of *Nestoritherium;* it has been considered to be nearly allied to *Rhinoceros pachygnathus*. This species is of rare occurrence, but is known by an

[1] Syn. *Rhinoceros irvaticus* and *R. planidens*.

associated cranium and mandible, in the Museum of St. Andrew's University; by the upper molars of each maxilla and a mandible in the British Museum, and by a few lower molars in the Indian Museum. The latter specimens are from Sind, and the others from the Sub-Himalaya. Another species has been described from the pliocene of China. It seems doubtful whether the genus *Tapirus* occurs; the symphysis of a mandible from the Irawádi valley has indeed been referred to it, but the determination cannot be considered certain[1]. Fossil remains of the genus have, however, been obtained from the pliocene of China. The genus *Listriodon*, sometimes referred to the pigs, is represented by *L. pentapotamiæ* and *L. theobaldi*, the former being known by several molars, and the latter only by one molar of small size. All these teeth were obtained from the Panjáb, and are in the Indian Museum.

The horses are represented by the genera *Equus* and *Hippotherium* (*Hipparion*); of the former there are two species, *viz.*, *E. sivalensis*, apparently closely allied to the Tibetan kiang (*E. hemionus*), but retaining some ancestral characters, and *E. namadicus*, more nearly allied to the existing horse. Remains of these species have been obtained from the Sub-Himalaya, and one species of the genus from Perim, of which there are three molars in the Museum of Trinity College, Dublin. Of *Hippotherium* there are also two species, *viz.*, *H. antelopinum*, closely allied to the European *H. gracile*, and *H. theobaldi*, distinguished by its superior size, and the form of its upper milk-molars. The former has been obtained from the Sub-Himalaya and Perim Island, and there are numerous remains both in the British and Indian Museums. A fine skull from Perim has been recently sent on loan to the Indian Museum, and is the only known example. The latter has been obtained from the Panjáb, Burma, and Perim Island, and most of its remains are in the Indian Museum; it is not improbable that the range of this species extended to China, where molars belonging to some form of the genus have been obtained. Coming to the artiodactylates, we have among the bunodont pig-like animals two species of *Hippopotamus*, one of which, *H. sivalensis*, was of large size, and furnished with six incisors in either jaw; the other, *H. iravaticus*, is very imperfectly known, but seems to have been of small size. Remains of these species have been obtained from the Sub-Himalaya and the Irawádi valley. A large animal, *Tetraconodon magnum*, is known only by a broken mandible, from the Panjáb, in the Indian Museum, and of which there is a cast in the Museum of the Royal College of Surgeons, and by a figure of the upper dentition. The mandible is remarkable for the enormous size of the premolars, and indicates an animal allied to the European and American tertiary genus *Entelodon* (*Elotherium*), but distinguished by the greater relative size of the premolars, and the more regularly oblong form of the true molars. The true pigs (*Sus*) are represented by three species, the first of which, *S. giganteus*, is distinguished by its enormous size; there is a nearly complete skull, with the mandible attached, and with some of the limb-bones, of this fine species, as well as numerous other remains in the Indian Museum, and a large series of teeth and jaws in the British Museum, all of which have been obtained from the Panjáb and Sub-Himalaya. The second species, *S. hysudricus*, is smaller

[1] Remains of *Listriodon* have been described as *Tapirus*.

than the living wild-boar, and has been obtained from the Panjáb, Sub-Himalaya, Perim Island, and Sind. The last species, *S. punjabiensis*, is of very small dimensions, and is only known by two portions of the mandible from the Panjáb, now in the Indian Museum. *Hippohyus* is a genus peculiar to the Siwaliks, whose molars present a remarkable complex arrangement of the columns, recalling the pattern of the molars of the horse; it appears to have been represented by two species, both from the Sub-Himalaya, and one of which has been named *H. sivalensis*. *Sanitherium* is another genus peculiar to the Siwaliks, and is represented only by *S. schlagintweiti*, of which three fragments of the mandible are known, two being in Germany and the third in the Indian Museum; all three are from the Panjáb and Sub-Himalaya. The European miocene genus *Hyotherium* is represented by the molars of one species from Sind and Perim Island, which has been named *H. sindiense;* these teeth are in the Indian Museum. Of the selenodont pig-like animals, we have, among the group with five columns on the upper molars, two species of *Anthracotherium*, and two of *Hyopotamus*. Of the former, one species, *A. silistrense*, is of small size, and is known by three upper molars, and parts of the mandible; these specimens have been obtained from near Sylhet, the Panjáb, and Sind, and most of them are in the Indian Museum. The second species, *H. hyopotamoides*, is of large size, and is known by an upper molar in the Indian Museum, from the Bhúgti hills, to the north of Sind; some mandibles may also belong to this species. Of *Hyopotamus*, a small species, *H. palæindicus*, is known by several teeth and one lower jaw, from Sind, in the Indian Museum; the molars of this species differ somewhat from those of typical species. The second species, *H. giganteus*, is known by an upper molar, and by some specimens of the mandible from the Bhúgti hills, now in the Indian Museum [1]; the upper tooth much resembles that of *Anthracotherium hyopotamoides*, and with that species forms such a complete transition between the genera *Anthracotherium* and *Hyopotamus* that it seems highly probable that the two should be united. Among the forms characterised by having only four columns on the upper molars, there are four peculiar genera, each of which is known only by a single representative. The best known of these is *Merycopotamus*, represented by *M. dissimilis*, a genus allied to the hyopotamids by the structure of its teeth, and to the hippopotamus by the form of the mandible; this species has been obtained from the Sub-Himalaya and the Irawádi valley, and there are fine series of its remains in both the British and the Indian Museums. A second genus, *Hemimeryx*, is only certainly known by an upper molar of somewhat similar structure to the molars of the last genus; this specimen has been named *H. blanfordi*, and was obtained from Sind; it is now in the Indian Museum. Another upper molar in the same collection, also from Sind, has been named *Sivameryx sindiensis*, and indicates a smaller animal allied to the above. A maxilla with the upper molars, from the Garo hills, presented to the Geological Society, indicates another small animal of the same group, to which the name *Chœromeryx silistrensis* has been applied.

[1] Casts of the teeth of this species and of *A. hyopotamoides* will be found in the British Museum. The names of these, and of other selenodont Suina, are mentioned here for the first time, the memoir in which they are described being still in the press.

A single upper molar from Sind, in the Indian Museum, belongs to the American family *Oreodontidæ*, and has been provisionally referred to the genus *Agriochœrus*; it seems to be very close to the American *A. latifrons*.

Among the true ruminants we have the deer family represented by several imperfectly known species, at least one of which had large branching antlers. Of these, *Cervus triplidens* had a large accessory column to the molars, while in *C. simplicidens*, a species as large as *C. kashmirianus*, the accessory column is much smaller. In *C. sivalensis* the molars had very low crowns. The genus of the fourth species, *C. latidens*, is somewhat doubtful. Remains of these species have been obtained from the Panjáb and the Sub-Himalaya, and are numerously represented in the Indian Museum. The genus *Dorcatherium* is represented by the two species *D. majus* and *D. minus*, of which there are teeth in the Indian Museum, obtained from the Panjáb. A single upper molar in the Indian Museum, from the Panjáb, seems to belong to a genus related to *Palæomeryx*, for which the provisional name *Propalæomeryx sivalensis* has been proposed; it probably connects the true deer with the giraffe. The family *Camelopardalidæ*, which is taken to include both the giraffes and the sivatheres, is represented by several genera. In these we have a true giraffe, distinguished as *Camelopardalis sivalensis*, of which there are numerous teeth and a few bones in the British and Indian Museums, from the Sub-Himalaya, the Panjáb, and Perim Island. A species of *Helladotherium*, not distinguishable from *H. duvernoyi* of Europe, is represented by a single cranium in the British Museum. Of four genera peculiar to the Siwaliks, the first, *Vishnutherium*, is known by a part of the mandible from Burma, and probably by two upper molars, and some bones from the Panjáb, all of which are in the Indian Museum. It seems to come the nearest of the four to the giraffe, and has been named *V. iravaticum*. The second, *Hydaspitherium*, is known by two species, of which *H. megacephalum* is known by a skull and a large series of teeth and bones, all from the Panjáb, and now in the Indian Museum; it carried a massive common horn-base above the occiput, from which the horns took their origin. The second species, *H. grande*, was larger and is only known by the upper molars and the mandible, all from the Panjáb, and now in the Indian Museum. It is probable that a cervical vertebra from Beluchistan, in the collection of the Geological Society, belongs to one of the above species. The third genus, *Bramatherium*, is represented by *B. perimense*, of which the skull, teeth, mandible, and some of the limb-bones are known; this species carried a pair of horns above the occiput, and a large common horn-base on the frontals. Its remains have been obtained from Perim Island, and the one known skull is in the Museum of the Royal College of Surgeons, the upper molars in the British Museum, two fragments of the mandible in the Indian Museum, and another, with the last true molar, in the Museum of Trinity College, Dublin. The fourth genus is the well-known *Sivatherium* represented by the one species, *S. giganteum*, in which the skull was furnished with two pairs of horns. Remains of this species have been obtained only from the Sub-Himalaya eastward of the Panjáb, and the British Museum possesses a magnificent series of them. There has been much discussion as to the serial position of the foregoing forms, *Helladotherium*, with the giraffe, being classed by

some with the stags, while *Sivatherium* and the two preceding genera are classed with the antelopes. The resemblance of the teeth of all these animals is, however, so close that it seems preferable to class them all together in one large family, connecting the deer with the antelopes.

Of the antelopes, the best known is the so-called *Antilope palæindica*, which seems to have been closely allied to the South African genus *Damalis* (Bonte-bok, and Sassaby), and should probably be termed *D. palæindica;* there are two skulls in the Indian and one in the British Museum, all from the Sub-Himalaya. A skull from the same locality, in the Indian Museum, indicates a second species of antelope closely allied to the living Indian *A. cervicapra*, which has been named *A. sivalensis*. A third species, *A. acuticornis*, is indicated by numerous horn-cores from the Panjáb, in the Indian Museum, and was probably a kind of gazelle. A fourth species, *A. patulicornis*, has been named from a pair of horn-cores in the same collection. A species of *Portax* is indicated by numerous teeth and a fore-limb, in the Indian Museum; while other molars in the same collection not improbably belong to the genus *Palæoryx*, of the Pikermi beds. The oxen are represented by numerous species, three of which are here referred to one genus under the name of *Hemibos*, but have also been referred to two genera under the names of *Probubalus* and *Amphibos;* the group is closely allied to, if not identical with, the living Celebes genus *Anoa*, which has been referred to it under the name of *Probubalus celebensis*. The first species of *Hemibos* is named *H. occipitalis*, and varies considerably in the form of its horn-cores, which are sometimes nearly straight and triangular in section, and at others curved and pyriform in section; another variety is hornless. There are fine series of the skulls of this species, both in the British and the Indian Museums, all from the Sub-Himalaya. The second species, *H. antilopinus*, is also known by several skulls from the same districts. The third species *H.* (*Amphibos*) *acuticornis*, is a long-horned form, and is also represented by numerous skulls, from the Sub-Himalaya, in the British and Indian Museums. *Leptobos falconeri* is a fourth form of ox, which was in some cases hornless, of which there are several crania in the British Museum. The genus *Bubalus* is represented by two species; the first of these, *B. platyceros* (*sivalensis*), is known by one cranium in the British and another in the Indian Museum, both from the Sub-Himalaya; the horns were stout and concave superiorly. The second species is *B. palæindicus*, which occurs also in the pleistocene, if, indeed, the topmost beds of the Siwaliks in which it occurs should not be referred to that period; this species is evidently only a race of the living *B. arni*, and is very probably the same as *B. pallasi* from the pleistocene of Danzig. One skull from the Sub-Himalaya, in the Indian Museum, belongs to a species of *Bubalus*, and has been named *B. sivalensis;* it is the earliest form of the genus, and seems to have been allied to the fossil European *B. priscus*. Of the true oxen (*Bos*), three species have been named, *viz.*, *B. acutifrons*, remarkable for its enormous horns and angulated frontals; *B. planifrons*, with shorter horns and flattened frontals, and closely allied to the European *B. primigenius;* and *B. platyrhinus*, only known by the lower half of a skull of which the generic affinities are doubtful. The latter specimen, as well as a skull of each of the preceding species, are in the Indian Museum, and came from

the Sub-Himalaya. Species of *Bos* or allied genera are indicated from Perim Island by molars in the Museum of Trinity College, Dublin.

A remarkable hornless skull, of comparatively large size, from the Sub-Himalaya, in the collection of the British Museum, has been described under the name of *Bucapra daviesi;* this skull comes nearest to the skulls of the goats, while the molars are of a bovine type, and, if found separately, would certainly have been referred to some form of oxen. There is evidence of three species of true goats, the first of which, *Capra sivalensis*, is known by two skulls in the British Museum, from the Sub-Himalaya, and is considered to be allied to the jharal of the Nilgherries (*Hemitragus jemlaicus*), and not improbably belongs to the same genus. The second species, *C. perimensis*, is known by a portion of a skull in the Indian Museum from Perim Island, and was probably allied to the living markhoor (*C. falconeri*) of the Himalaya, though the horn-cores do not show a spiral twist. The third species is unnamed, since its horn-cores, of which the Indian Museum possesses numerous specimens from the Panjáb, are so like those of the markhoor that it is difficult to point out characters of specific distinction with the materials available; it is possible that the horns may belong to older individuals of *C. perimensis*. It has been stated that a cranium from the Sub-Himalaya, which is not now forthcoming, belongs to the living Himalayan ibex (*C. sibirica*), but this determination requires confirmation, although it is highly likely that the specimen may have belonged to an allied species. Another cranium, also lost, has been referred to the genus *Ovis*.

A species of chevrotain has been determined from the evidence of a single upper molar, from the Panjáb, in the Indian Museum, under the name of *Tragulus sivalensis*.

The camels are known by *Camelus sivalensis*, which presents a peculiarity in the structure of its lower molars, connecting it with the llamas (*Auchenia*) of America. Remains of this species have been obtained from the higher beds of the Sub-Himalayan Siwaliks, and are well represented in both the British and Indian Museums.

The remaining orders of the mammalia are only represented by a few species of rodents, and by one edentate. Of the former, a species of rat (*Mus*) is indicated by some incisors from the Sub-Himalaya. A species of bambú-rat (*Rhizomys sivalensis*[1]) has been determined on the evidence of three specimens of the mandible from the Panjáb now in the Indian Museum. A porcupine (*Hystrix sivalensis*) is known by a part of the cranium and the mandible, the former being in the British and the latter in the Indian Museum; one is from the Sub-Himalaya and the other from the Panjáb.

The edentates are known by one species of pangolin, *Manis sindiensis*, named on the evidence of a solitary phalangeal bone from Sind, now in the Indian Museum. The species must have been about four times the size of the living Indian *M. pentedactylus*.

Pleistocene.—Coming to the pleistocene, we find that its mammals are even less well known than those of the pliocene. As the pleistocene ossiferous strata are distributed in patches, very frequently in the valleys of the great rivers, the

[1] Probably the same as *Typhlodon* of Falconer.

remains from the more important of these areas must be treated of separately. The most important areas are parts of Madras and the Deccan; the valleys of the Jamna, Narbada, Pemganga, Krishna (Kistna), and Godávari, with their numerous tributaries, and the plains of Húndes in Tibet. It is also not improbable, as already mentioned, that the topmost strata of the Sub-Himalayan Siwaliks should really be referred to the pleistocene. In many instances, as in the delta of the Ganges, it is difficult, if not impossible, to draw any satisfactory line of distinction between the pleistocene and the prehistoric deposits. The presence in any stratum of the remains of *Hippopotamus*, or other genus not now found living in India, is considered as fair evidence for assigning such deposit to the pleistocene.

From the laterite of Madras palæolithic implements and a human platycnemic tibia have been obtained, and are assigned to the pleistocene.

From the alluvium of the Krishna valley, in the Deccan, a part of the skull and the mandible of a rhinoceros have been obtained and described under the name of *Rhinoceros deccanensis*. This species seems to be more nearly allied to the living African and the pliocene European species than to any living Indian form. Remains of an ox, not improbably *Bos namadicus*, have also been obtained from the same deposits, and, with the last-mentioned specimens, are in the Indian Museum. Certain molars of the pliocene *Mastodon pandionis* from the Deccan, and now in the British Museum, were not improbably derived from the same deposits in the upper part of the Krishna basin.

From the ossiferous gravels of the Narbada palæolithic implements of a rude form have been found associated with mammalian bones. The carnivora are represented by a small species of bear (*Ursus namadicus*), of which there are a maxilla and a tibia in the British, and a canine in the Indian Museum; and a large species of *Felis* is indicated by the distal extremity of a femur in the former collection. Of the Proboscidia, there is *Euelephas namadicus*, characterised by its prominent frontal ridge, and whose molars very closely resemble those of the European *E. antiquus*, from which resemblance it has been thought that the two forms may belong to the same species. The Indian species has also been obtained from Japan. There is one fine skull in the British Museum, and three skulls in the Indian Museum. *Stegodon* is represented by *S. ganesa*, of which there is a fine tusk in the Indian Museum, and very probably by *S. insignis*. The perissodactyles are represented by *Rhinoceros indicus*, of which the Indian Museum has two molars, and by a little-known extinct form to which the name *R. namadicus* has been applied; there is a scapula of this species in the last-named collection. There is also a species of horse, *Equus namadicus*, which seems to be a survivor from the Siwaliks. Among the Artiodactyla two species of hippopotamus were originally described under the names of *Hippopotamus namadicus* and *H. palæindicus*; the former having six, and the latter four, incisors. Specimens in the Indian Museum seem, however, to show that there is a transition in these respects between these two so-called species, and all the remains have accordingly been referred to *H. palæindicus*, which was hexaprotodont in some individuals, and tetraprotodont in others. The pigs seem to have been represented by *Sus giganteus*, another survivor from the Siwaliks. Remains of a deer

apparently very close to, if not identical with, the living Indian *Cervus duvaucelli*, have been obtained, and there is some evidence of a second species. Three species of oxen have been described, *viz.*, *Bos namadicus*, a species showing some affinity to the Asiatic genus *Bibos*, of which there is a magnificent skull in the Indian Museum; *Bubalus palæindicus*, also occurring in the topmost Siwaliks, and the ancestor of *B. arni*; and *Leptobos frazeri*, which was sometimes hornless, and is represented by some fine skulls in the British Museum. A species of nilghai, of which there are two broken crania in the same collection, has been named *Portax namadicus*; it is distinguished from the living species, among other characters, by the horns being placed nearer to the orbits. The rodents are only known by some incisors in the Indian Museum, probably belonging to a species of *Mus*.

From the pleistocene of the Jamna valley only four mammals have been specifically determined with any certainty, *viz.*, *Euelephas namadicus*, *Bubalus palæindicus*, *Hippopotamus palæindicus*, and the living *Antilope cervicapra*; the latter being known by a single horn-core in the Indian Museum. In addition to these, remains of a species of *Semnopithecus*, *Sus*, *Portax*, *Equus*, *Mus*, and of a *Rhinoceros* furnished with lower incisors, have also been obtained. A tiger, as large as the existing species, is indicated by a scapho-lunar bone in the Indian Museum; this species was very probably the same as the Narbada form, and may have been *Felis tigris*.

The pleistocene of the Pemganga valley has yielded remains of *Bos namadicus*, a *Portax*, and *Hippopotamus palæindicus*.

The remains from the Godávari deposits have not been satisfactorily determined.

The horizontal lacustrine strata of Húndes in Tibet formerly classed as Siwalik, but which are more probably of pleistocene age, have yielded a small number of mammalian remains. Among these is a tooth referred to a species of *Hyæna*. Bones belonging to some form of horse have also been obtained, among which a cannon-bone in the collection of the Geological Society belongs to a species of *Hippotherium*, a genus elsewhere unknown in the pleistocene. Several of the limb-bones and the fragment of an upper molar of a rhinoceros are also known, but they are too imperfect for specific determination. The other known fossils belong to ruminants, the best preserved of which is the greater portion of the skull of an antelope, provisionally referred to the living Tibetan genus *Pantholops*, under the name of *P. hundesiensis*; this specimen cannot now be found, but is figured in Royle's "Illustrations of the Botany of the Himalaya Mountains." There is also a skull said to belong to some genus of bovine animal; another belonging to a goat resembling the markhoor (*Capra falconeri*); and a palate, in the collection of the Geological Society, doubtfully referred to a sheep (*Ovis*).

It may be added that mammalian remains are stated to have been obtained from a cave in the Karnúl district of Madras; these remains have, however, never been described, and cannot now be found.

Prehistoric.—The prehistoric deposits, as already said, have in many cases not yet been satisfactorily separated from the pleistocene, and the very local

occurrence of vertebrate remains in the former renders this point of doubt not likely to be soon cleared up. Any old alluvial deposit in which bones of ‹ living mammals occur is here provisionally referred to the prehistoric.

Human remains and neolithic implements have been obtained in the ı vium of the plains in many localities, and frequently at considerable dista below the surface; the former are generally very imperfectly preserved and] never been carefully examined. Polished celts are extremely abundant in n places, and particularly in Burma and the Banda district of the North-West vinces. The prevailing types are elongated forms with oval section, wedges, the "shouldered" form. Among the mammals specimens of the teeth and of *Macacus rhesus* from the alluvium and turbary of Goalpára, in Assam, from Madras are exhibited in the Indian Museum, those from the for district being in a highly mineralised condition. Molars of the Indian elep occur at considerable depths in the alluvium of the plains and of Burma last upper molar of *Rhinoceros indicus*, in the Indian Museum, was obta from the turbary of Madras, and indicates the former extensive range of species. It may be observed, in passing, that the range of the other speci *Rhinoceros* was probably much more extensive than at present, even in historic period, because it has been inferred that the species killed by A on the banks of the Indus was *R. javanicus* (*Sondaicus*), this inference b founded on the improbability of its being possible to kill *R. indicus* by mea arrows, with which Akbar's animals were destroyed. *Sus indicus* has also obtained from the turbaries of Madras and Calcutta. Antlers, horn-cores, teeth of undetermined species of *Bos* and *Cervus* have been obtained from alluvium of various districts in the plains, and from raised beaches in Kattia some of the latter deposits being probably in part of pleistocene age.

General.—Of the mammalia as a whole it may be observed that those of pliocene are characterised by the great number of forms belonging to the o which include animals of large corporeal bulk. Another noticeable point is admixture of genera characteristic of modern Africa (*Hippopotamus*, *Ca pardalis*) and other parts of the old world (*Bos*, *Capra*, *Ursus*, *Equus*, etc. oligocene, miocene, and pliocene Europe (*Dinotherium*, *Anthracotherium*, *H therium*, etc.) with those now peculiar to Asia (*Euelephas*, *Rhinoceros* [in its res ed sense] etc.). Among orders which have now diminished extensively in nun in India, the Proboscidia stands pre-eminent, its fourteen Siwalik represents having now dwindled to one. The perrissodactylate Ungulata have also dimin considerably, the modern forms inhabiting India and the adjacent countries five and the extinct eleven or twelve. The artiodactylate modification has pe suffered a still more serious diminution, especially among the pig-like anima which the whole of the selenodont group like *Merycopotamus* and *Hyopo* has completely disappeared, while their congener, the hippopotamus, is now fined to Africa, and the Indian wild-boar and the diminutive terai hog (*Por* are the sole representatives now remaining. The ruminants have lost their l representatives, either entirely (*Sivatherium*) or by transference to Africa (*Ca pardalis*), and some of their smaller forms are considered to be allied to S Indian (*Hemitragus*) or South African form (*Damalis*), while others have a

been exclusively Indian (*Portax*). The diminution in numbers of the ruminants cannot be clearly indicated owing to the numbers of small forms now existing, when analogues cannot be determined in the Siwaliks. Similarly, owing to the poverty of the remains of the other orders, and of the almost total absence of the micro-mammalia, comparisons cannot be instituted between the numbers of the recent and fossil species, but enough has been indicated to show that modern India has only the impoverished remains of a once extensive fauna of mighty forms. Regarding the range in space of the Siwalik fauna, it is probable that this was once very extensive, as we find some of the species ranging as far as China and Japan, and it has even been suggested that one species (*Hyænarctos sivalensis*) occurs in the pliocene of England. Representatives of some of the other common Siwalik or Indian genera, although considered to be specifically distinct, have also been obtained from China (*e.g.*, *Chalicotherium*, *Rhinoceros*, *Tapirus*, and *Hyæna*). It may also be observed that the mammals from Sind belong mainly to European oligocene and miocene genera, while those from the Panjáb show a mixture of miocene, pliocene, and existing genera; the two latter prevailing more extensively, as we proceed eastward along the Sub-Himalaya. The high degree of evolution or specialisation of many of the genera is a marked feature, and one strongly confirmative of their pliocene age. Thus, it may be noticed that the rhinoceroses had high-crowned molars, and that in one form the incisors were absent and two horns present; while some of the horses had reduced their digits to one on each limb. The pigs had well-developed tusks, the deer large branching antlers, the oxen wide-spreading horns, and the cats (*Machairodus*) huge trenchant fangs.

In the pleistocene the majority of the larger forms had disappeared, though a few of the extinct genera and species still lingered on. Many of the existing species were already in existence, or were represented by closely allied forms. Palæontological history is, however, still silent as to the origin of some of the larger existing mammals, like the Indian elephant. Some new forms (*e.g.*, *Bos namadicus*), which cannot be directly traced back to pliocene ancestors, seem to have appeared and to have died out again before the prehistoric.

In the latter period all the mammals seem to belong to existing species, although the range in space of some of them was more extensive than at present.

SYSTEMATIC CHRONOLOGICAL LIST OF SPECIES.

A.—ANTHROPOZOIC.

a.—PREHISTORIC.

MAMMALIA .	. PRIMATES .	. Homo (? sapiens, Lin.).
		Macacus rhesus (F. Cuv.).
	PROBOSCIDIA .	. Euelephas indicus, Linné.
	UNGULATA .	. Rhinoceros indicus, Cuvier.
		Sus indicus, Gray.
		Cervus, sp.
		Bos, sp.
REPTILIA .	. CHELONIA .	. Gen. *non det.*

b.—PLEISTOCENE.

MAMMALIA .	. PRIMATES . . .	Homo, sp.
		Semnopithecus, sp.
		Ursus namadicus, F. & C.
		Hyæna, sp.
		Felis (? tigris, Lin.).
	PROBOSCIDIA . .	Euelephas namadicus, F. & C.
		Stegodon ganesa, F. & C.
		(?) —— insignis, F. & C.
		Mastodon pandionis, Fals.
	UNGULATA . .	Rhinoceros deccanensis, Foote.
		—— indicus, Cuv.
		—— namadicus, F. & C.
		—— sp.
		Equus namadicus, F. & C.
		Hippotherium, sp.
		Sus giganteus, F. & C.
		Cervus (? duvaucelli, Cuv.).
		Bubalus palæindicus, F. & C.
		Bos namadicus, F. & C.
		Leptobos frazeri, Rüt.
		Portax namadicus, Rüt.
		Antilope cervicapra, Pallas.
		Pantholops (?) hundesiensis, Lyd.
		Capra, sp,
		Ovis, (?) sp.
	RODENTIA . .	Mus, sp.
REPTILIA .	. CROCODILIA . .	Crocodilus, (?) sp.
	CHELONIA . .	Pangshura tectum (Bell).
		Batagur (? dhongoka, Blyth).
		Trionyx (? gangeticus, Cuv.).

B.—THERIOZOIC.

a.—PLIOCENE [1].

MAMMALIA .	. PRIMATES . . .	Palæopithecus sivalensis, Lyd.
		Macacus sivalensis, Lyd.
		—— sp.
		Semnopithecus (?) sub-himalayanus, Myr.
		—— sp.
	CARNIVORA . .	Felis cristata, F. & C.
		—— sp.
		Machairodus sivalensis, F. & C.
		Pseudælurus sivalensis, F. & C.
		Ictitherium sivalense, Lyd.
		Viverra bakeri, Bose.
		Hyæna sivalensis, F. & C.
		Canis curvipalatus, Bose.
		—— cautleyi, Bose.
		† Amphicyon palæindicus, Lyd.
		Ursus, sp.

[1] The forms of the earlier pliocene are marked by a cross (†).

[M]AMALIA .	. **CARNIVORA** .	. **Hyænarctos sivalensis, F. & C.**
		——— palæindicus, Lyd.
		Mellivora sivalensis, F. & C.
		Meles, sp.
		Lutra palæindica, F. & C.
		—— sp.
		Enhydriodon sivalensis, F. & C.
	PROBOSCIDIA .	. **Euelephas hysudricus, F. & C.**
		Loxodon planifrons, F. & C.
		Stegodon ganesa, F. & C.
		——— insignis, F. & C.
		——— bombifrons, F. & C.
		——— clifti, F. & C.
		† Mastodon latidens, Clift.
		——— sivalensis, F. & C.
		† ——— perimensis, F. & C.
		† ——— pandionis, Falc.
		† ——— falconeri, Lyd.
		† Dinotherium sindiense, Lyd.
		† ——— pentapotamiæ, Falc.
		——— indicum, Falc.
	UNGULATA .	. **† Chalicotherium sivalense, F. & C.**
		Rhinoceros palæindicus, F. & C.
		——— platyrhinus, F. & C.
		† ——— sivalensis, F. & C.
		† Acerotherium perimense, F. & C.
		Listriodon pentapotamiæ, Falc.
		——— theobaldi, Lyd.
		(?) Tapirus sp.
		Equus sivalensis, F. & C.
		—— namadicus, F. & C.
		Hippotherium antilopinum, F. & C.
		——— theobaldi, Lyd.
		Hippopotamus iravaticus, F. & C.
		——— sivalensis, F. & C.
		Tetraconodon magnum, Falc.
		Sus giganteus, F. & C.
		† — hysudricus, F & C.
		— punjabiensis, Lyd.
		Hippohyus sivalensis, F. & C.
		——— sp.
		Sanitherium schlagintweiti, Myr.
		† Hyotherium sindiense, Lyd.
		† Anthracotherium silistrense (Pent).
		† ——— hyopotamoides, Lyd.
		† Hyopotamus palæindicus, Lyd.
		† ——— giganteus, Lyd.
		Merycopotamus dissimilis, F. & C.
		Chœromeryx silistrensis (Pent).
		† Hemimeryx blanfordi, Lyd.
		† Sivameryx sindiensis, Lyd.
		† Agriochœrus, (?) sp.
		Cervus triplidens, Lyd.
		——— sivalensis, Lyd.

MAMMALIA .	. UNGULATA .	.	Cervus simplicidens, Lyd.
			——— (?) latidens, Lyd.
			Dorcatherium majus, Lyd.
			——— minus, Lyd.
			Propalæomeryx sivalensis, Lyd.
			Camelopardalis sivalensis, F. & C.
			Helladotherium duvernoyi, Wag.
			Vishnutherium iravaticum, Lyd.
			Hydaspitherium grande, Lyd.
			——— megacephalum, Lyd.
			Sivatherium giganteum, F. & C.
			Antilope (? Damalis) palæindica, F. & C.
			——— patulicornis, Lyd.
			——— (? Gazella) porrecticornis, Lyd.
			——— sivalensis, Lyd.
			Palæoryx, (?) sp.
			Portax, sp.
			Hemibos occipitalis, Falc.
			——— acuticornis, Falc.
			——— antilopinus, Falc.
			Leptobos falconeri, Rüt.
			Bubalus platyceros, Lyd.
			——— palæindicus, F. & C.
			Bison sivalensis, Falc.
			Bos acutifrons, Lyd.
			—— planifrons, Lyd.
			—— (?) platyrhinus, Lyd.
			Bucapra daviesi, Rüt.
			Capra (? Hemitragus) sivalensis, Lyd.
			—— perimensis, Lyd.
			—— sp.
			Ovis, (?) sp.
			Tragulus sivalensis, Lyd.
			Camelus sivalensis, F. & C.
	RODENTIA .	.	Mus, sp.
			Rhizomys sivalensis, Lyd.
			Hystrix sivalensis, Lyd.
	EDENTATA .	. †	Manis sindiensis, Lyd.
AVES . .	. CARINATÆ .	.	Graculus, (?) sp.
			Pelecanus cautleyi, Dav.
			——— (?) sivalensis, Dav.
			Megaloscelornis sivalensis, Lyd.
		†	——— (?) sp.
			Argala falconeri, M. Ed.
	RATITÆ . .	.	Struthio asiaticus, M. Ed.
			Dromæus sivalensis, Lyd.
			Gen. *non det.*
REPTILIA .	. CROCODILIA .	.	Crocodilus, palustris, Less.
			Gharialis gangeticus, Gmel.
			——— leptodus, F. & C.
		†	——— crassidens, F. & C.
	LACERTILIA .	.	Varanus sivalensis, Falc.
	OPHIDIA . .	. †	Python (? molurus, Lin.).
	CHELONIA .	.	Colossochelys atlas, F. & C.

EPTILIA .	. CHELONIA . .	Testudo (?) 5, sp.
		Bellia sivalensis, Theo.
		—— sp.
		Damonia hamiltoni, Gray.
		Emys, sp.
		Cantleya annuliger, Theo.
		Pangshura tectum (Bell).
		† Batagur, sp.
		† Trionyx, sp.
		Emyda vittata, Pet.
ISCES . .	. ELASMOBRANCHII .	Carcharias, sp.
		Lamna, sp.
	TELEOSTEI . .	Bagarias yarrelli, Syk.
		Arius, sp.
		Gen. *non. det.*

b.—MIOCENE.

IAMMALIA .	. UNGULATA . .	Rhinoceros sivalensis v. gajensis, Lyd.

c.—EOCENE.

IAMMALIA .	. UNGULATA . .	(?) Palæotherium, sp.
		Artiodactyle, gen. *non det.*
EPTILIA .	. CROCODILIA . .	Gen. *non det.*
	CHELONIA . .	Hydraspis leithi, Carter.
MPHIBIA .	. ANOURA . . .	Oxyglossus pusillus, Owen.
		———(?) sp.
ISCES . .	. ELASMOBRANCHII .	Myliobatis, sp.
	TELEOSTEI . .	Diodon foleyi, Lyd.
		Capitodus indicus, Lyd.
		Gen. *non det.*

C.—SAUROZOIC.

a.—CRETACEOUS.

EPTILIA .	. DINOSAURIA . .	Megalosaurus, sp.
		Titanosaurus blanfordi, Lyd.
		———indicus, Lyd.
		Gen. *non det.*
	CROCODILIA . .	Gen. *non det.*
	CHELONIA . .	Gen. *non det.*
	ICHTHYOSAURIA . .	Ichthyosaurus indicus, Lyd.
SCES . .	. ELASMOBRANCHII .	Corax incisus, Eg.
		———pristodontus, Ag.
		Enchodus serratus, Eg.
		Lamna complanata, Eg.
		——— sigmoides, Eg.
		Odontaspis constrictus, Eg.
		———oxypeion, Eg.
		Otodus basalis, Eg.
		——— divergens, Eg.
		——— marginatus, Eg.
		——— minutus, Eg.
		——— nanus, Eg.
		——— semiplicatus, Eg.

PISCES . .	. ELASMOBRANCHII .	Oxyrhina triangularis, Ag.
		——— sp.
		Ptychodus latissimus, Ag.
		Sphyrænodus, (?), sp.
	GANOIDEI . .	Pycnodus (?), sp.

b.—JURA-TRIAS.

REPTILIA .	. DINOSAURIA . .	Ankistrodon indicus, Hux.
	CROCODILIA . .	Gen. *non det.* (Chari gp.).
		Parasuchus hislopi, Hux. Mss.
		Gen. *non det.* (Rewah.).
	LACERTILIA . .	Hyperodapedon huxleyi, Lyd.
	DICYNODONTIA . .	Dicynodon orientalis, Hux.
		——— sp.
	PLESIOSAURIA . .	Plesiosaurus indicus, Lyd.
AMPHIBIA .	. LABYRINTHODONTIA .	Brachyops laticeps, Owen.
		Gonioglyptus longirostris, Hux.
		——— huxleyi, Lyd.
		Glyptognathus fragilis, Lyd.
		Pachygonia incurvata, Hux.
		Archegosaurus, (?), sp.
		Gen. *non det.*
PISCES . .	. GANOIDEI . .	Ceratodus [1] hislopianus, Old.
		——— hunterianus, Old.
		——— virapa, Old.
		Dapedius egertoni, Syk.
		Lepidotus breviceps, Eg.
		——— calcaratus, Eg.
		——— deccanensis, Eg.
		——— longiceps, Eg.
		——— pachylepis, Eg.
		Tetragonolepis analis, Eg.
		——— oldhami, Eg.
		——— rugosus, Eg.
		Gen. *non* det.

D.—ICHTHYOZOIC.

CARBONIFEROUS.

PISCES . .	. GANOIDEI . . .	Sigmodus dubius, Waag.
		Pœcilodus paradoxus, Waag.
		Psephodus indicus, Waag.
		Saurichthys indicus (?), De Kon.
	ELASMOBRANCHII .	Helodopsis elongata, Waag.
		——— abbreviata, Waag.
		Psammodus, sp.
		Petalorhynchus indicus, Waag.
		Xystracanthus gracilis, Waag.
		——— major, Waag.
		——— giganteus, Waag.
		Thaumatacanthus blanfordi, Waag.
		Acrodus flemingi, De Kon.
		——— sp.

[1] Following Professor Miall ("Monograph of the Sirenoid and Crossopterygian Ganoids," Palæontograpl Society, 1878), the order Dipnoi is merged with the Ganoidei.

ALPHABETICAL AND SYNOPTICAL LIST OF SPECIES, ARRANGED IN CLASSES[1].

CLASS I.—PISCES.

Acrodus flemingi, De Kon.	Salt-range	Carboniferous.
—— sp.	"	"
Arius	Panjáb and Sind	Pliocene.
‡ Bagarias yarrelli, Sykes *Pimelodus bagarias*, Syk.	Sub-Himalaya	Higher pliocene.
Capitodus indicus, Lyd.	Panjáb	Eocene.
Carcharias, sp.	Burma	Higher pliocene.
Ceratodus hislopianus, Old.	Maleri	Trias-jura.
—— hunterianus, Old.	"	"
—— virapa, Old.	"	"
Corax incisus, Eg.	Trichinopoli	Cretaceous.
—— pristodontus, Ag.	Trichinopoli and Europe	"
Dapedius egertoni, Syk.	Kota	Trias-jura.
Diodon foleyi, Lyd.	Rámri and Andamans	Eocene.
Enchodus serratus, Eg.	Trichinopoli	Cretaceous.
* Helodopsis abbreviata, Waag.	Salt-range	Carboniferous.
—— elongata, Waag.	"	"
Lamna complanata, Eg.	Trichinopoli	Cretaceous.
—— sigmoides, Eg.	"	"
—— sp.	Burma	Higher pliocene.
Lepidotus breviceps, Eg.	Kota	Trias-jura.
—— calcaratus, Eg.	"	"
—— deccanensis, Eg.	"	"
—— longiceps, Eg.	"	"
—— pachylepis, Eg.	"	"
Myliobatis, sp.	Panjáb	Eocene.
Odontaspis constrictus, Eg.	Trichinopoli	Cretaceous.
—— oxypeion, Eg.	"	"
Otodus basalis, Eg.	"	"
—— divergens, Eg.	"	"
—— marginatus, Eg.	"	"
—— minutus, Eg.	"	"
—— nanus, Eg.	"	"
—— semiplicatus, Eg.	"	"
Oxyrhina triangularis, Eg.	"	"
—— sp.	"	"
Petalorhynchus indicus, Waag.	Salt-range	Carboniferous.
Poecilodus paradoxus, Waag.	"	"
Psammodus, sp.	"	"
Psephodus indicus, Waag.	"	"
Ptychodus latissimus, Ag.	Trichinopoli and Europe	Cretaceous.
Pycnodus, (?) sp.	Trichinopoli	"
Saurichthys indicus (?), De Kon.	Salt-range	Carboniferous.
* Sigmodus dubius, Waag.	"	"
Sphyraenodus, (?) sp.	Lameta gp.	Cretaceous.

[1] Synonyms (of which only the more important are given) are in italics; living species are indicated by a double cross (‡), and fossil genera peculiar to India or Burma by an asterisk (*).

Tetragonolepis analis, Eg.	Kota	Trias-jura.
——— oldhami, Eg.	"	"
——— rugosus, Eg.	"	"
* Thaumatacanthus blanfordi, Waag.	Salt-range	Carboniferous.
Xystracanthus giganteus, Waag.	"	"
——— gracilis, Waag.	"	"
——— major, Waag.	"	"

CLASS II.—AMPHIBIA.

Archegosaurus, (?) sp.	Bijori gp.	Trias-jura.
* Brachyops laticeps, Owen.	Mangli	"
* Glyptognathus fragilis, Lyd.	Panchet gp.	"
* Gonioglyptus huxleyi, Lyd.	"	"
* ——— longirostris, Hux.	"	"
Oxyglossus pusillus, Owen (*Rana pusilla*, Owen).	Bombay	Eocene.
——— (?) sp.	"	"
* Pachygonia incurvata, Hux.	Panchet gp.	Trias-jura.

CLASS III.—REPTILIA.

* Ankistrodon indicus, Hux.	Panchet gp.	Trias-jura.
‡ Batagur (? dhonkoka, Blyth)	Narbada	Pleistocene.
Bellia sivalensis, Theo.	Panjáb	Higher pliocene.
—— sp.	"	"
* Cautleya annuliger, Theo.	"	"
* Colossochelys atlas, F. & C.	Sub-Himalaya and Burma	"
‡ Crocodilus palustris, Less. (*C. bombifrons*, Gray.)	Sub-Himalaya and (?) Narbada.	Higher pliocene: (?) pleistocene.
‡ Damonia hamiltoni, Gray (*Emys hamiltonoides*, Falc.) (*Damonia hamiltonoides*, Falc.)	Sub-Himalaya	Higher pliocene.
Dicynodon orientalis, Hux. (*Ptychognathus orientalis*, Hux.)	Panchet gp.	Trias-jura.
‡ Emyda vittata, Peters (*E. ceylonensis*, Gray.)	Sub-Himalaya, &c.	Higher pliocene.
Emys, sp.	"	"
‡ Gharialis crassidens, F. & C. (*Crocodilus crassidens*, F. & C.) (*Leptorhynchus crassidens*, F. & C.)	Sub-Himalaya and Sind	Pliocene.
‡ ——— gangeticus, Gmel. (*Leptorhynchus gangeticus*, Gmel.)	Sub-Himalaya, Burma, Sind, and Perim.	"
——— leptodus, F. & C. (*Leptorhynchus leptodus*, F. & C.)	Sub-Himalaya, Burma, Sind, and Perim	"
Hydraspis leithi, Carter (*Testudo leithi*, Carter.)	Bombay	Eocene.
Hyperodapedon huxleyi, Lyd.	Maleri and South Rewá	Trias-jura.
Ichthyosaurus indicus, Lyd.	Trichinopoli	Cretaceous.
Megalosaurus, sp.	Trichinopoli and Lameta gp.	"
‡ Pangshura tectum, Bell (*Emys tectum*, Bell).	Sub-Himalaya and Narbada.	Higher pliocene pleistocene.

• Parasuchus hislopi, Hux.	Maleri	Trias-jura.
——— (?), sp.	Denwa gp.	„
Plesiosaurus indicus, Lyd.	Umia gp.	Jura.
‡ Python (? molurus, Lin.)	Panjáb and Sind	Pliocene.
Testudo, *sp. var.*	Sub-Himalaya	Higher pliocene.
• Titanosaurus blanfordi, Lyd.	Lameta gp.	Cretaceous.
——— indicus, Lyd.	„	„
‡ Trionyx (? gangeticus, Cuv.)	Narbada	Pleistocene.
——— sp.	Sub-Himalaya	Higher pliocene.
Varanus sivalensis, F. & C.	„	„

CLASS IV.—AVES.

Argala falconeri, M. Ed. (*Leptoptilus falconeri* [M. Ed.])	Sub-Himalaya	Higher pliocene.
Dromœus sivalensis, Lyd.	„	„
Graculus (?), sp.	„	„
Megaloscelornis sivalensis, Lyd.	„	„
Pelecanus cautleyi, Dav.	„	„
——— (?) sivalensis, Dav.	„	„
Struthio asiaticus, M. Ed. (*S. palæindicus*, Falc.)	„	„

CLASS V.—MAMMALIA.

Acerotherium perimense, F. & C. (*Rhinoceros iravaticus*, Lyd.) (——— *perimensis*, F. & C.) (——— *planidens*, Lyd.)	Panjáb, Burma, Perim, and Sind	Pliocene.
Agriochœrus (?)	Sind	Earlier pliocene.
Amphicyon palæindicus, Lyd.	Panjáb and Sind	Pliocene.
Anthracotherium hyopotamoides, Lyd.	Bhúgti hills	Earlier pliocene.
——— silistrense, Pent. (*Chæromeryx silistrensis*, Pent.) (*Rhagatherium ? sindiense*, Lyd.) (*A. punjabiense*, Lyd.)	Sind, Gáro hills, and Panjáb	„
‡ Antilope cervicapra, Pallas (*A. bezoarctica*, Ald.)	Jamna	Pleistocene.
——— palæindica, F. & C. (*Damalis* (?) *palæindica*, F. & C.)	Sub-Himalaya	Higher pliocene.
——— patulicornis, Lyd.	„	„
——— porrecticornis, Lyd. (*Gazella* (?) *porrecticornis*, Lyd.)	„	„
Bison sivalensis, Falc.	„	„
Bos acutifrons, Lyd.	„	„
— namadicus, F. & C.	Narbada, &c.	Pleistocene.
— planifrons, F. & C.	Sub-Himalaya	Higher pliocene.
— platyrhinus, Lyd.	„	„
— (?) sp.	Perim	„
• Bramatherium perimense, Falc. (*Sivatherium*, sp., Owen.)	„	„
Bubalus palæindicus, F. & C.	Sub-Himalaya, Narbada, &c.	Higher pliocene and pleistocene.
——— platyceros, Lyd.[1] (*B. sivalensis*, Rüt.)	Sub-Himalaya	Higher pliocene.

* Bucapra daviesi, Rüt.	Sub-Himalaya	Higher pliocene.
Camelopardalis sivalensis, F. & C. (*C. affinis*, F. & C.)	Sub-Himalaya and Perim	"
Camelus sivalensis, F. & C.	Sub-Himalaya	"
Canis cautleyi, Bose.	"	"
—— curvipalatus, Bose.	"	"
Capra perimensis, Lyd.	Perim	"
—— sivalensis, Lyd. (*Hemitragus sivalensis*, Lyd.)	Sub-Himalaya	"
—— sp.	"	"
—— sp.	Tibet	Pleistocene (?).
‡ Cervus (? duvaucelli, Cuv.)	Narbada	"
—— (?) latidens, Lyd.	Sub-Himalaya	Higher pliocene.
—— simplicidens, Lyd.	"	"
—— sivalensis, Lyd.	"	"
—— triplidens, Lyd.	"	"
Chalicotherium sivalense, F. & C. (*Anoplotherium sivalense*, F. & C.) (*Nestoritherium sivalense*, Wag.)	Sub-Himalaya and Sind	Pliocene.
Chœromeryx silistrensis, Pent. (*Anthracotherium silistrense*, Pent.)	Gáro hills	Higher pliocene.
Dinotherium indicum, F. & C.	Panjáb and Perim	"
—— pentapotamiæ, Falc.	Panjáb, Kách, and Sind	Pliocene.
—— sindiense, Lyd.	"	"
Dorcatherium majus, Lyd. (*Merycopotamus nanus*, Falc.)	Panjáb	Higher pliocene.
—— minus, Lyd.	"	"
* Enhydriodon ferox, F. & C. (*E. sivalensis*, F. & C.) (*Amyxodon*, F. & C.)	Sub-Himalaya	"
Equus namadicus, F. & C. (*E. palæonus*, F. & C.)	Sub-Himalaya and Narbada	Higher pliocene and pleistocene.
—— sivalensis, F. & C.	Sub-Himalaya and (?) Perim	Higher pliocene.
‡ Euelephas indicus, Lin. (*Elephas indicus*, Lin.)	Plains and Burma	Prehistoric.
—— hysudricus, F. & C. (*Elephas hysudricus*, F. & C.)	Sub-Himalaya	Higher pliocene.
—— namadicus, F. & C.) (*Elephas namadicus*, F. & C.)	Narbada, &c.	Pleistocene.
Felis cristata, F. & C. (*F. grandicristata*, Bose.) (*F. palæotigris*, F. & C.) (*Uncia cristata*, Cope.)	Sub-Himalaya	Higher pliocene.
—— sp.	"	"
‡ —— (? tigris, Lin.)	Jamna and Narbada	Pleistocene.
Helladotherium duvernoyi, Wag.	Sub-Himalaya	Higher pliocene.
* Hemibos acuticornis, F. & C. (*Amphibos acuticornis*, F. & C.) (*Leptobos acuticornis*, Falc.)	"	"
—— antilopinus, F. & C.) (*Amphibos antilopinus*, F. & C.) (*Leptobos antilopinus*, Falc.)	"	"

Hemibos occipitalis, Falc.	Sub-Himalaya.	Higher pliocene.
(*H. triquetriceros*, F. & C.)		
(*Bos occipitalis*, Falc.)		
(*Leptobos triquetricornis*, Falc.)		
(*Peribos occipitalis*, Lyd.)		
(*Probubalus triquetricornis*, Rüt.)		
* Hemimeryx blanfordi, Lyd.	Sind	Earlier pliocene.
Hippopotamus iravaticus, F. & C.	Sub-Himalaya and	
(*Hexaprotodon iravaticus*, F. & C.)	Burma	Higher pliocene.
——— palæindicus, F. & C.	Narbada, &c.	Pleistocene.
(*Hexaprotodon namadicus*, F. & C.)		
(*Hippopotamus namadicus*, F. & C.)		
(*Tetraprotodon palæindicus*, F. & C.)		
——— sivalensis, F. & C.)	Sub-Himalaya	Higher pliocene.
(*Hexaprotodon sivalensis*, F. & C.)		
* Hippohyus sivalensis, F. & C.	"	"
——— sp.	"	"
Hippotherium antilopinum, F. & C.	Sub-Himalaya and	
(*Equus antilopinus*, F. & C.)	Perim	"
(*H. gracile*, Myr.)		
——— theobaldi, Lyd.	Burma, Perim, and	
(*Sivalhippus theobaldi*, Lyd.)	Sub-Himalaya	"
(*H. gracile*, Myr.)		
——— sp.	Tibet	Pleistocene (?).
* Hydaspitherium grande, Lyd.	Sub-Himalaya	Higher pliocene.
——— megacephalum, Lyd.	"	"
(*H. leptognathus*, Lyd.)		
Hyæna sivalensis, F. & C.	"	"
(*H. felina*, Bose.)		
——— ? sp.	Tibet	Pleistocene (?).
Hyænarctos sivalensis, F. & C.	Sub-Himalaya and	
(*Ursus sivalensis*, F. & C.)	Panjáb	Higher pliocene.
——— palæindicus, Lyd.	Panjáb	"
(? *Dinocyon*.)		
Hyopotamus giganteus, Lyd.	Bhúgti hills	Earlier pliocene.
——— palæindicus, Lyd.	Sind	"
Hyotherium sindiense, Lyd.	"	"
Hystrix sivalensis, Lyd.	Sub-Himalaya	Higher pliocene.
Ictitherium sivalense, Lyd.	Panjáb	"
Leptobos falconeri, Rüt.	Sub-Himalaya	"
——— frazeri, Rüt.	Narbada	Pleistocene.
Listriodon pentapotamiæ, Falc.	Panjáb	Higher pliocene.
(*Tapirus pentapotamiæ*, Falc.)		
——— theobaldi, Lyd.	"	"
Loxodon planifrons, F. & C.	Sub-Himalaya	"
(*Elephas planifrons*, F. & C.)		
‡ Macacus rhesus, F. Cuv.	Plains	Prehistoric.
——— sivalensis, Lyd.	Sub-Himalaya	Higher pliocene.
——— sp.	"	"
Machairodus sivalensis, F. & C.	"	"
(*M. falconeri*, Pomel.)		
(*M. palæindicus*, F. & C.)		
(*Drepanodon sivalensis*, F. & C.)		
Manis sindiensis, Lyd.	Sind	Earlier pliocene.

Mastodon falconeri, Lyd.	Panjáb & Sind	Pliocene.
——— latidens, Clift. (*M. elephantoides*, Clift.)	Sub-Himalaya, Burma, Panjáb, and Sind	"
——— pandionis, Falc.	Sub-Himalaya, Sind, Perim, and Deccan.	Pliocene and pleistocene.
——— perimensis, F. & C.	Sub-Himalaya, Sind, and Perim	Pliocene.
——— sivalensis, F. & C.	Sub-Himalaya	Higher pliocene.
Meles, sp.	Panjáb	"
Mellivora sivalensis, F. & C. (*Ursitaxus sivalensis*, F. & C.)	"	"
* Merycopotamus dissimilis, F. & C. (*M. sivalensis*, F. & C.) (*Hippopotamus dissimilis*, F. & C.)	Sub-Himalaya and Burma	"
Mus, sp.	Sub-Himalaya	Higher pliocene.
—— sp.	Narbada	Pleistocene.
Ovis, (?) sp.	Sub-Himalaya	Higher pliocene.
——, (?) sp.	Tibet	Pleistocene.
* Palæopithecus sivalensis, Lyd.	Panjáb	Higher pliocene.
Palæoryx, (?) sp.	"	"
Palæotherium, (?) sp.	"	Eocene.
Pantholops, (?) hundesiensis, Lyd.	Tibet	Pleistocene (?).
Portax namadicus, Rüt.	Narbada, &c.	"
——— sp.	Panjáb	Higher pliocene.
Propalæomeryx sivalensis, Lyd.	Sub-Himalaya	"
Pseudælurus sivalensis, Lyd.	Panjáb	"
Rhinoceros deccanensis, Foote.	Madras	Pleistocene.
‡ ——— indicus, Cuv.	Madras and Narbada	Prehistoric and Pleistocene.
——— namadicus, F. & C.	Narbada	Pleistocene.
——— palæindicus, F. & C.	Sub-Himalaya	Higher pliocene.
——— sivalensis, F. & C.	Sub-Himalaya and Sind	Pliocene.
———— var. gajensis, Lyd.	Sind	U. Miocene.
Rhizomys sivalensis, Lyd. ((?) *Typholodon*, Falc.)	Panjáb	Higher pliocene.
* Sanitherium schlagintweiti, Myr. (*Sus pusillus*, Falc.)	Sub-Himalaya and Panjáb	"
Semnopithecus sub-himalayanus, Myr.	Sub-Himalaya	"
——— sp.	"	"
——— sp.	Jamna	Pleistocene.
Sivameryx sindiensis, Lyd.	Sind	Earlier pliocene.
* Sivatherium giganteum, F. & C.	Sub-Himalaya	Higher pliocene.
Stegodon bombifrons, F. & C. (*S. orientalis*, Owen.) (*Elephas bombifrons*, F. & C.)	Sub-Himalaya and (?) China	"
——— clifti, F. & C. (*S. sinensis*, Owen.) (*Elephas clifti*, F. & C.) (*Mastodon elephantoides*, Clift.)	India, Burma, China, and Japan	"
——— ganesa, F. & C. (*Elephas ganesa*, F. & C.)	Sub-Himalaya and Narbada.	Higher pliocene and pleistocene.

Stegodon insignis, F. & C. (*Elephas insignis*, F. & C.)	Sub-Himalaya, Japan, China and (?) Narbada.	Higher pliocene and (?) pleistocene.
Sus giganteus, F. & C. (*Hippopotamodon*, Lyd.)	Sub-Himalaya and Narbada.	Higher pliocene and (?) pleistocene.
— **hysudricus, F. & C.**	Sub-Himalaya, Sind, and Perim	Pliocene.
‡ — **prædicus, Gray.** (*S. cristatus*, Wag.)	Madras	Prehistoric.
— **punjabiensis, Lyd.**	Sub-Himalaya.	Higher pliocene.
Tapirus (?) sp.	Burma	"
* **Tetraconodon magnum, Falc.**	Sub-Himalaya	"
Tragulus sivalensis, Lyd.	Panjáb	"
Ursus namadicus, F. & C.	Narbada, &c.	Pleistocene.
— **sp.**	Sub-Himalaya.	Higher pliocene.
* **Vishnutherium iravaticum, Lyd.**	Burma and (?) Panjáb	"
Viverra bakeri, Bose (*Canis* sp., Baker and Durand.)	Sub-Himalaya.	"

Note on the Bijori Labyrinthodont—*By* R. LYDEKKER, B.A., F.G.S., F.Z.S.

As it is always expedient to correct erroneous determinations as speedily as possible, I have thought it advisable to publish a preliminary note regarding the large labyrinthodont skeleton from the Bijori group of the Gondwánas[1], which has recently come into my custody. Careful 'development' has exposed a considerable portion of the palatal aspect of the skull, which was previously concealed by matrix. As I hope eventually to describe and figure this important and interesting specimen, which has hitherto been considered as probably belonging to *Archegosaurus*, in the "Palæontologia Indica," it will only be very briefly noticed on this occasion.

The skull, which is the only part that need now be mentioned, is triangular in shape, and has a length of about 11, with an extreme breadth of 8, inches. The orbits are oval and placed somewhat posteriorly. The teeth are small, subcylindrical, and regular; there are several larger "tusks" close to the symphysis of the mandible, placed (as in *Mastodonsaurus*, *Labyrinthodon*, and *Pachygonia*) interiorly to the row of small teeth. This character alone shows that the specimen cannot belong to *Archegosaurus*. The structure of the teeth seems to be less complex than in the first three of these genera, but more so than in the last. The skull is greatly produced at its postero-external angles, and has large epiotic cornua, thereby differing from *Mastodonsaurus*. The mandible has apparently no distinct post-articular process, but a well-developed internal articular buttress. The palatine foramina are large and approximated.

Except in the apparent absence of a distinct post-articular process to the mandible, the skull shows decided affinity to the first division of the Euglypta[2]; in that respect, however, it agrees with *Loxomma*, but is distinguished by the

[1] See "Manual," part I, p. 128.
[2] See "British Association Report," 1874, p. 150.

characters of the teeth and orbits. The specimen will almost certainly have to be referred to a new genus.

It may not be out of place to mention that in describing the lower jaw of *Glyptognathus fragilis*, represented in figure 1 of the plate accompanying my last notice of Gondwána labyrinthodonts[1], the specimen, from the presumed absence of a post-articular process, was inferred to belong probably to the Brachiopina. It should have been stated, assuming the correctness of the inference as to the absence of the process, that it probably belonged to the Brachiopina, or some of the subsequent sections of Professor Miall's classification[2].

Note on a skull of Hippotherium antilopinum, *by* R. LYDEKKER, B.A., F.G.S., F.Z.S.

Among a small collection of Siwalik fossils from Perim Island lent by Mr. Theodore Cooke, LL.D., F.G.S., of Poona, and transmitted to me for determination, there is a very fine example of the skull of *Hippotherium antilopinum*. The species was previously unknown from Perim, and this is the first known example of the skull. It shows the complete molar dentition of the left side. and is otherwise fairly perfect: I shall hope to give a further description of it on a future occasion.

The Lodge, Harpenden, Herts.

On the Iron Ores, *and* Subsidiary Materials *for the* Manufacture of Iron, *in the North-Eastern part of the* Jabalpur District; *by* F. R. MALLET, F.G.S., *Geological Survey of India.* (With a map.)

From time immemorial the Jabalpur district has held an important place amongst those centres where the smelting of iron has been carried on in the native method. Plentiful ores, extensive jungles for the supply of charcoal, and proximity to thickly populated alluvial tracts of country, combined to give Jabalpur a commanding position in the old days, before railways had brought the native hearths into an unequal struggle with the blast-furnaces of England. Even now iron is made on what, from the native point of view, must be considered a large scale, numerous furnaces being scattered over the iron-bearing portions of the district.

The advantageous central position of Jabalpur, now that it is in railway communication with the richest parts of the surrounding provinces, is too great to have escaped notice with reference to the manufacture of iron on European principles. As far as was known, ores and flux were to be had in abundance, and the means for distributing the manufactured iron to the surrounding markets was at hand. But the often-experienced difficulty of keeping large furnaces in blast with charcoal, and the absence of any available coal, were a deterrent to any decisive action.

[1] "Records," Vol. XV, p. 27.

[2] "British Association Report," *loc. cit.*

Within the last year or two, however, the discovery of workable coal by Mr. T. W. H. Hughes, in the immediate neighbourhood of the Jabalpur district, has given the question a new aspect. A line of railway from the new coal-field at Umeria to Murwára (Katni), on the East Indian line, has been proposed, and the preliminary surveys already executed.

The question of fuel, then, being in a fair way towards a satisfactory solution, it became important to ascertain whether the generally received opinion as to the abundance and excellence of the Jabalpur ores was fully borne out by fact. I was consequently directed, in the early part of this year, to visit the more important places where iron was known to occur, with a view to forming an opinion as to the extent of the deposits, and the feasibility of working them, and to collect samples for subsequent analysis. The question of flux and other subsidiary materials was also to be looked into. The following paper, then, embodies the results of my work in the field and laboratory.

The iron ores, for purposes of description, may be regarded with reference either to their mineralogical characteristics, their geological distribution, or their topographical position. The accompanying map, the geological work on which is mainly, and indeed, with reference to the area with which we are more immediately concerned, exclusively, due to surveys executed by Mr. C. A. Hacket in 1869-72, shows the distribution of the different series of rocks. It will be seen that between the great spread of Vindhyan sandstones on the north and Deccan trap on the south, both of which formations are almost barren of any metallic wealth, there is a belt, some 30 miles wide, where a very varied and intricately disposed assemblage of rocks occurs. It is just here that the band of iron-bearing transition strata, which stretches eastwards for more than 200 miles through the Son Valley, comes in contact with the thickly populated alluvial belt through which the Narbadda flows westwards for about the same distance. Hence one of the most important advantages which the iron-smelters of Jabalpur have enjoyed. Hematite ores similar to those of Jabalpur are known to occur largely in the wild country to the east; but there are not the same facilities there for disposing of the manufactured product.

The formations just mentioned include—

Alluvium.
Rock laterite.
Deccan trap.
Lameta group.
Upper Gondwána.
Coal measures.
Tálchir group.
Upper Vindhyans.
Lower „
Bijáwar or transition series.
Gneiss.

The Bijáwar series and the rock laterite are those with which we are more immediately concerned now, for it is in them that nearly all the iron ore is con-

tained[1]. By reference to the map, then, one sees at a glance the general lie of the iron-bearing tracts, which are those coloured respectively purple and burnt sienna, although it is only in certain portions of those areas that the ores are found. The Bijáwar ores occur more especially in the Parganas Khumbhi and Gosulpur, while the Pargana Bijerágogarh contains the greater portion of the lateritic ores.

Mineralogically considered, the iron ores are almost exclusively varieties of hematite and limonite (or red and brown hematite), the former being especially characteristic of the Bijáwars, and the latter of the newer formation. They may be classified thus—

BIJÁWAR ORES	1, *Hematite*	Schistose hematite. Micaceous iron. Jasper-hematite[2]. Semi-ochreous hematite. Manganiferous hematite.
	2, *Limonite.*	
LATERITE ORES	1, *Limonite*	Pisolitic limonite, breaking with smooth conchoidal fracture. Pisolitic limonite, breaking with rough uneven fracture. Ordinary laterite, some parts of which contain a high percentage of iron.
	2, *Hematite.*	

Magnetite has been found in small crystals disseminated through the hematite beds of Sehora, but I am not aware of its occurring anywhere in such quantity as to entitle it to be included in the above list as an ore.

BIJÁWAR ORES.

The Bijáwar series has been subdivided by Mr. Hacket thus (in descending order) :—

Chandardíp group.
Lora "
Bhítri "
Majhauli "

It is in the inferior strata of the Lora group (so called from the Lora range east of Sehora) that all the most important existing mines are sunk[3]. "All the iron-workings," says Mr. Hacket, "are situated near the base of the (Lora) group, where the quartz bands[4] are absent, and the rocks consist almost entirely of micaceous iron, or mixed with a few bands of clay. The Jauli mines are so situated, as also those of Mangela, and at Agaria in the Majgaon hills, and also

[1] Some ore also occurs in the Gondwána beds, but it is "very impure and requires much selection and cleaning" and is "very rarely worth working" (J. G. Medlicott, Memoirs, Geological Survey of India, Vol. II, p. 278).

[2] *Vide* p. 100.

[3] Here, and subsequently, in reference to native operations, I use the word 'mine' to express an excavation where ore is extracted, irrespective of its form. Underground workings are rather the exception than the rule, the majority of the excavations being irregular open pits.

[4] *Vide* p. 100.

in the hills west of the 'marble rocks'. This band of rich iron appears to be very constant in the section, but, being softer than the rocks above, is mostly worn away, and covered by the alluvium, or debris from the ridges of the harder rocks; but that the band exists is shown by the pieces of rich iron strewn along the line."[1]

A few workings in the Majhauli hills (near the western edge of the map) are situated in rocks of the Bhítri group, but these are of very secondary importance[1].

Probably the most extensively worked cluster of mines in the district are those situated in the group of low irregular hills south of Sarroli and Majgaon (8 miles south-east of Sehora), and as the iron-bearing strata are exposed there more clearly, and on a larger scale, than in any other localities that I have visited, it will be convenient to take that neighbourhood as a starting point in any detailed descriptions.

Hill ¼ mile south of Agaria.

The hill half a mile south of Agaria (4 miles west-south-west of Sarroli) appears to be formed entirely of iron ore. The strata have a low irregular dip towards the south. The highest beds, *i.e.*, those on the south side of the hill, where there are numerous pits, are of evenly laminated micaceous iron, interbanded with occasional argillaceous layers. The rock is so soft that it can be powdered between the fingers, and is simply dug out with ordinary *kodalis*. But the greater portion of the ore, constituting the lower beds, is schistose hematite, which is harder than the micaceous iron, although easily worked on account of its fissile character. Numerous pits have been sunk into it also. There is a thin skin of laterite on the top of the hill, which is, in great part at least, and I believe wholly, due to alteration of the iron-schist *in situ*.

As this hill is about a third of a mile long, flat-topped, and wide, and not far from 100 feet high, the quantity of ore available by open workings, with free drainage, is enormous. As a very rough estimate, the cubic contents of the hill may perhaps be taken at $\frac{600 \times 450 \times 30}{2}$, or about four million cubic yards[2], which is equivalent to about fourteen million tons of ore. Even then if a liberal deduction be made for possible concealed bands of useless rock, the remaining figures will represent an immense amount of ore.

A sample of schistose hematite from the northern side of the hill yielded on analysis—

Ferric oxide	97·54	= Iron 68·28
Phosphoric acid	·12	
Sulphuric acid	trace	
Sulphur	traces	
Loss on ignition[3]	·89	
Ignited insoluble residue	1·21	
Alumina and undetermined	·24	
	100·00	

[1] MSS. report, 1870-71.

[2] The product of the dimensions of the hill is divided by 2 to allow for the slopes and irregularities.

[3] This and the other ores analysed were air dried. The loss on ignition, therefore, includes hygroscopic moisture, as well as, in the case of the hydrous ores, chemically combined water.

Ridge at Agaria.

In the low ridge which runs westward from Agaria a band of hematite schist, several yards thick, is visible along the crest. Elsewhere the rock is obscured by talus, &c. Except, however, near the base of the southern slope, where pieces of ferruginous sandstone are strewn, the *debris* on the ridge is entirely of hematite schist, so that considerably more ore may exist than is actually seen. The ridge is perhaps 40 to 50 feet high, and comparatively wide, with gentle slopes. Even if the hematite band is not thicker than the exposed strata, a large amount of ore is available in the ridge. The dip, as seen about half a mile west of the village, is to the south at 40°—50°.

Hills south-east of Agaria.

In the hills south-east of Agaria I observed runs of ore in two or three places, but nothing of much importance. At the western end of the Jhíti ridge some limonite schist is seen, dipping S. 20° E. at 40°, but no good section is exposed. This, as well as other Bijáwar limonite ores, which are of rather unfrequent occurrence, may possibly be due to hydration of hematitic strata near the surface. At the southern base of the hillock just west of Kurumukur, jaspery quartz schist interbanded with micaceous iron is seen. The hillock is capped by laterite, and similar rock is to be seen in some of the hills to the north-east of the same village. These hills are low and featureless, with little or no other rock visible. It is not at all improbable, however, that the laterite is due to superficial alteration of iron ore, and that there is a considerable, perhaps a large, quantity of the latter in the hills in question.

Sarroli.

There are two low hillocks close to Sarroli, one three-quarters of a mile somewhat south of west, and the other a mile south-south-west from the town. The former of these is composed of schistose hematite and micaceous iron, the beds of which have an irregular strike, corresponding on whole with the direction of the hill, and an uncertain dip at high angles. There is a skin of laterite in places due, I have no doubt, to superficial alteration of the ore.

The northern part of the other hill is also composed of iron ore, which has an irregular dip, apparently towards the south as a whole. The southern part of the hill is formed of hornstone. The lower beds of ore, *i.e.*, those in the most northern part of the hill, are of hard micaceous iron passing into schistose hematite, while the upper strata are of soft, crumbly, finely laminated micaceous iron, with some interbanded argillaceous layers. It will be observed that the section here is similar to that in the hill half a mile south of Agaria—soft crumbly ore above and harder beds beneath—and I do not think there can be much doubt that the strata in the two localities belong to the same horizon. There are two rather large excavations in the upper beds; that to the south-east is known as the Sarroli mine, and that to tho north-west as the Partábpur mine (from a village close by which is not marked on the map).

As a rough estimate of the amount of ore available by open workings, with free drainage, in the Sarroli hills, the cubic contents of the northern may perhaps be taken at $\frac{500 \times 150 \times 13}{2}$, or about 500,000 cubic yards, and that of the iron-bearing part of the southern at $\frac{300 \times 200 \times 17}{2}$, or about the same amount. This is equivalent to about 1,700,000 tons of ore in each hill, or say three and a half million tons

in both together. In this estimate, as in that for the hill south of Agaria, no account is taken of the ore which could be raised from open workings beneath the level of the surrounding country. From such workings an immense amount of ore could be obtained.

A sample of the crumbly micaceous iron from the Partábpur mine, taken as it was being loaded on to buffaloes for transmission to the neighbouring furnaces, yielded—

Ferric oxide	92·21	= Iron 64·55
Phosphoric acid	·07	
Sulphuric acid	trace	
Sulphur	trace	
Loss on ignition	1·86	
Ignited insoluble residue	4·50	
Lime, alumina and undetermined	1·36	
	100·00	

The harder ore from the north end of hill gave—

Ferric oxide	97·16	= Iron 68·02
Loss on ignition	1·30	
Ignited insoluble residue	·89	
Undetermined [1]	·65	
	100·00	

The largest iron mine in the district is that near Jauli, somewhat less than a mile south-east of the village (3 miles south-east of Sarroli). The ore is a semi-ochreous hematite, in which a slightly schistose structure is often apparent. Hematite with metallic lustre also occurs, but is quite subordinate to the more ochrey kind. The ore is interbanded with quartzose layers, which in some places greatly exceed the ferruginous part of the rock. In other places they are comparatively rare, and in the best ore they are still less common. These layers vary from a fraction of an inch to several inches in thickness. The beds are vertical, the strike, where best seen, being N. 40° E. A rough measurement showed the beds exposed to have a thickness of about 150 feet, but in estimating the thickness of ore, a deduction must be made as an allowance for the quartzose portion just alluded to.

Jauli.

The ore has been very largely worked, the mine being nearly 100 yards long by 50 yards broad, and perhaps 50 feet deep. I was informed by Mr. Olpherts' agent in charge of the mine, that it is not flooded in the rains; it is a sort of deep trench (the length of which coincides with the strike of the rock) in which water would accumulate if it did not soak away subterraneously, or evaporate, quicker than it entered. The surrounding country is an undulating one, and without actual levelling it would be impossible to say to what extent free drainage could be depended on for more extensive operations.

It is from picked ore from this mine that Mr. W. G. Olpherts' 'metallic paint' is made, by grinding to an impalpable powder.

[1] In this, and subsequent analyses, in which phosphorus and sulphur are not given separately, any present is included in the undetermined portion of the ore.

Some distance, perhaps a quarter of a mile, to the north-east of the above mine, there is an old abandoned one. The ore exposed is not as rich as that in the mine now worked, and naturally so, as previous to abandonment all the best ore exposed would be removed. The beds dip E. 30° S. at 60°, the strike therefore being nearly the same as in the newer mine. Mr. Hacket considered the ore in both mines to belong to the same band, and one can scarcely doubt that such is the fact; but the ore is so soft that it makes no show at the surface, and hence cannot be traced along the outcrop. If the band is continuous, however, for even a quarter of a mile only, with anything like the thickness it has in the present mine, a very large amount of ore is hidden beneath the surface.

An average sample of the Jauli ore, taken as it came, and including the inter-banded quartz, yielded on analysis—

Ferric oxide	75·69 = Iron 52·98.
Phosphoric acid	·10
Sulphuric acid	traces.
Sulphur	traces.
Loss on ignition	1·59
Ignited insoluble residue	22·32
Manganese oxide, lime and undetermined	·30
	100·00

By the aid of some picking, however, a much purer ore can be obtained. A sample assayed by Mr. A. Tween gave 97·86 per cent. of ferric oxide = 68·50 of iron, and some of Mr. Olpherts' paint gave 97·10.

Ores of the Sarroli hills bedded, not fault, rock.

Before leaving the ores of this neighbourhood, I ought to mention that the hematite of Jauli and Agaria, as well as of the hills close to Sarroli, is most distinctly a bedded rock, having generally (except at Jauli, where it is less strong marked) a highly schistose character. Locally indeed the rock is crushed and recemented, and this crushing may have taken place along lines of faulting (probably merely local slips). But except in such very limited sense the ore is most certainly not a fault rock. The point is one of practical importance with reference to the probable persistency of the ore, and is alluded to as the reverse has been previously stated[1].

Lora Hills.

The most prominent rock in the Lora range (east of Sehora) is a ferruginous siliceous schist, composed of alternating layers of micaceous iron and quartz, which is usually of a red jaspery type. The layers are of irregular thickness, varying from a small fraction of an inch to an inch and upwards. For want of a better name, and to avoid circumlocution in referring to it, this rock may perhaps be called jasper-hematite schist. If it were marked as an iron ore, the Lora range (as well as many other lines of hill) should be streaked with gold from end to end. But a large proportion of the rock contains too great an amount of silica to allow of its being smelted with advantage, more especially when ores practically free from silica are to be obtained in abundance. Only those places, therefore, are marked with gold in which I have myself seen good workable ore.

[1] Memoirs, Geol. Surv. of India, Vol. II, p. 278.

North of Mangola.

At the termination of the range north of Mangola a band of jasper-hematite is exposed *in situ* along the crest. Lower down the slopes there is a talus of the same rock, amongst which pieces of micaceous iron 2 or 3 inches thick, or more, and free from siliceous layers, are not uncommon. But the beds are not exposed sufficiently for one to form an opinion as to whether there is any considerable quantity of ore.

Gogra and Danwai.

The hill half a mile north of Gogra is formed mainly of jasper-hematite. Near the base of southern slope there are a number of shallow ore pits[1], but they are only in talus, not in the rock *in situ*. The miners seek for the small bits of ore which can be used at once in the furnaces, and leave the large lumps, which would require the labour of breaking up. The ore is a manganiferous micaceous hematite, containing a varying proportion of interbanded jaspery quartz. It is a siliceous ore, although not very highly so. As the manganiferous band is entirely concealed beneath the talus, no estimate can be made of its thickness. Judging, however, from the large amount of *debris*, it seems probable that the thickness is considerable. As the loose ore must either lie directly over that *in situ*, or else have come down hill, and as the pits extend 20 or 30 feet (vertically) from the base of the hill, probably a large amount of ore is obtainable by dry open workings, whether these be through a deep mass of talus or into solid rock.

The proportion of manganese varies much, as can be seen from the outward appearance of the ore. In some specimens of the micaceous iron, the presence of manganese is scarcely apparent to the eye; in others, the ore shows by its dark colour that it contains a large amount, and in the highly manganiferous portions psilomelane occurs in irregular segregations. A carefully chosen average sample, made up of a large number of small pieces taken from different pits, yielded—

Ferric oxide	66·33	= Iron 46·43
{ Manganese (with traces of cobalt)	12·26	
{ Oxygen	6·83	
Phosphoric acid	·27	
Sulphuric acid	·03	
Sulphur	trace.	
Ignited insoluble residue	9·55	
Lime, alumina, water and undetermined	4·76	
	100·00	

The manganese exists, in large part at least, in the form of psilomelane, occurring in irregular segregations, or more minutely disseminated through the rock.

The Gogra miners told me (and Mr. Hacket mentions the same thing) that the ore from these pits produces a hard steely iron, used for making edged-tools, &c., while that from the mines in the Sarroli neighbourhood yields a soft iron, used largely for '*karrais*' (shallow basins for making *chupatis* in, &c.). The difference is no doubt to be attributed to the manganese in the former.

[1] Those to the west belong to the village Gogra, and those to the east to Danwai.

The ridge running eastward from Kuthola (1 mile south-east of Sehora) is formed mainly of jasper-hematite. At the gap where the railway passes, the strata dip at a high angle towards the south. In the low hill just west of the railway station (Sehora road), the beds in which seem to be higher in the section, as the rocks actually lie, than those just mentioned, manganiferous hematite schist, with psilomelane, is visible. The rock is more earthy and impure-looking than that at Gosulpur, which will be described presently, and contains a considerable amount of interbanded jasper and quartz. No great thickness is exposed, but the outcrop is of some importance, as indicating the position of the manganiferous band.

Kuthola.

Where the Deccan road passes the end of the ridge, jasper-hematite with hornstone is visible *in situ*, and pieces of psilomelane, &c., are scattered about.

On the northern slope of the hillock, about 300 yards N. 15° W. from the Dák Bungalow at Gosulpur, a strong band of manganiferous micaceous iron outcrops. In a little nalla at the foot of the hill the following section is exposed:—

Gosulpur.

	Feet.
Clay-slate, seen about	50
Somewhat ferruginous quartz schist	5
Obscured	20
Manganiferous micaceous iron	15 ?
" quartz schist	5
" micaceous iron, seen	35

The total thickness of ore actually seen being about 50 feet. The section is given in descending order, as the rocks lie, the dip being about 60° to N. 30° W.

The hillock just mentioned forms the eastern extremity of a low scarp, running from Gosulpur to W. 30° S. The scarp is capped by several yards of rock laterite, but lower dowh the slope (which faces to N. 30° W.) the mangano-ferruginous band outcrops in several places. It is fairly seen at intervals for about a third of a mile, and reveals its presence more obscurely, by occasional small outcrops, and by loose fragments, for at least a quarter of a mile more. As in the first third of a mile the outcrop is well above the plain (averaging perhaps 30 feet or so), there is, unless the band thins out considerably immediately westward of Gosulpur, which is not likely, some hundreds of thousands of tons to be had by dry open workings, and probably some millions by going deep enough.

The appearance of the rock shows (as at Gogra) that the proportion of manganese is very variable. The greater portion of it, at least, exists in the form of psilomelane, occurring partly as linings to small cavities in the rock, and in irregular segregations and masses, some of which contain some cubic feet of mineral. I am somewhat inclined to think that the psilomelane is most abundant where the schist has crushed and re-cemented, psilomelane being the cementing material. A sample of the more manganiferous part of the schist afforded 18·02 per cent. of manganese (with a little cobalt), while the psilomelane gave 83·20 per cent. of available peroxide.

Reviewing the above details, it will be seen that manganiferous micaceous hematite has been found in several places along the southern side of the Lora

range. One can scarcely feel much doubt as to there being a continuous band in that position. It is highly probable that the Gosulpur ore belongs to the same horizon, but whether it is a direct continuation of the same outcrop or not is more doubtful. The strata in the Lora range have a general dip towards the south-south-east at high angles, while the beds at Gosulpur dip N. 30° W. at about 60°. This may be a mere local feature, or it may indicate that the Lora and Gosulpur outcrops are on opposite sides of a synclinal flexure.

There does not appear to be any reason why the Gosulpur and Lora manganiferous ore should not form a suitable material for the manufacture of spiegeleisen. Although part of the manganese occurs in distinct segregations, a large proportion of it is minutely disseminated through the ore.

On the slope of the hillock at Gosulpur above mentioned, a little below the outcrop of the manganiferous ore, there is a band of limonite not less than 15 feet thick. It can be traced westwards for about the same distance as the other ore, to which it runs parallel. Some parts are very massive, the rock lying about in large blocks; others present a schistose appearance. At the time I took this to be a bedded Bijáwar rock, but I am not prepared to assert positively that it is so. Whether it be or not, a considerable quantity of ore (containing, however, a rather high percentage of phosphorus) is to be obtained from it. It yielded on analysis—

Ferric oxide	81·57	= Iron 57·10
Phosphoric acid	1·69	
Sulphuric acid	0·00	
Sulphur	traces [1]	
Loss on ignition	10·91	
Ignited insoluble residue	4·08	
Lime, alumina and undetermined	1·75	
	100·00	

LATERITIC ORES.

The pisolitic ores occur on a horizon near the base of the lateritic strata. "The bottom beds (of the group) consist of a coarse ferruginous sandstone, formed of rounded bits of quartz, sometimes as large as a pea, embedded in a hard ferruginous paste. Above this there are some beds of fine ferruginous earthy sandstone, containing badly preserved leaf-impressions. Resting upon these in some sections, there are several feet of a rich oolitic iron ore, covered by red, white, and purple clays, with bands of a coarse ferruginous sandstone interbedded, the whole capped by the ordinary rock laterite."[2]

There are two main varieties of pisolitic ore, one of which breaks with a smooth conchoidal fracture and shining surface; the other with a rough uneven fracture and dull lustreless surface. In the former the hardness and tenacity of the spherules, and of the cement in which they are embedded, are about equal, so that fracture takes indifferently through both parts of the rock. The difference of fracture in the other variety is due partly to the cement, and also the spherules,

[1] ·003.

[2] C. A. Hacket, MSS. report, 1871-72.

breaking with a dull uneven surface; partly to some of the spherules being dragged out of their sockets unbroken, so that the surface of the rock shows a number of roundel prominences and depressions. The conchoidal-fractured limonite is hard and brittle, the other much softer, and sometimes quite friable.

The spherules of the former vary in size from that of large peas downwards, so that the rock passes into oolitic limonite. Intimately associated with it in many sections is a highly ferruginous sandstone, which, when looked at under the lens, is seen to be composed of minute grains of quartz with an abundant limonitic cement. Sometimes the rock is free from spherules of limonite; more frequently such are scattered through it more or less abundantly. Thus it passes into the rich pisolitic ore in which grains of quartz are sometimes visible between the spherules, though more frequently the cement is, like the spherules themselves, purely limonitic. The sandstone and pisolitic ore are often found in juxta-position, with a sharp line of division between the two.

An immense number of small pits, most of which are now abandoned, are scattered over the lateritic area. The majority of those I visited are in the neighbourhood of Bijori (7 miles east-south-east from Murwára) and in the Kanhwára hills.

Bijori.

There is a quarry a quarter of a mile S. 15° W. from Bijori from which Mr. W. G. Olpherts obtained some of the ore smelted in his experimental works at Murwára. The section at one end comprises—

	Ft.	In.
a. Surface soil	1	0
b. Lateritic *debris*	1	6
d. Pisolitic limonite with conchoidal fracture	0	11
e. Ochreous, somewhat pisolitic, limonite with rough fracture	0	4
f, g. Semi-ochreous red oxide of iron, in onion-like nodules several inches in diameter	0	8
h. Lithomargic clay	0	7
i. Soft friable sandstone, seen	0	7

One hundred feet to the east, at the other end of the quarry, the section is as follows—

	Ft.	In.
a. Surface soil	1	0
b. Lateritic *debris*	1	0
c. Soft pisolitic limonite with rough fracture	3	4
d. Pisolitic limonite with conchoidal fracture	0	10
e. Ochreous, somewhat pisolitic, limonite with rough fracture	0	5
f. Pisolitic limonite with conchoidal fracture	0	4
g. Ochreous, somewhat pisolitic, limonite with rough fracture	0	5
h. Lithomargic clay, seen	0	10

In comparing the above two sections it will be observed that the band of semi-ochreous red oxide of iron in the first corresponds to $f + g$ in the second, or to one or other of them, the other having died out. In either case there is a change in mineral character laterally, which change may be either original or secondary. The absence of *c* in the first section is merely due to denudation.

About a mile south of Bijori there is another quarry, which has been worked by Mr. Olpherts. The section at the eastern end comprises—

	Ft.	In.
a. Surface soil	1	0
b. Disintegrated laterite, or lateritic *debris*	2	8
c. Disintegrated laterite with one or two layers of highly ferruginous sandstone, and thin seams of pisolitic limonite with conchoidal fracture	0	9
d. Pisolitic limonite with conchoidal fracture	0	3 to 4
e. Soft pisolitic limonite with rough fracture	1	9
f. Pisolitic limonite with conchoidal fracture	0	½
g. Soft pisolitic limonite with rough fracture	1	10
h. Limonite, with conchoidal fracture; pisolitic in the upper part, passing into oolitic lower down	0	11
i. Laterite, seen	1	2

At the other end of the quarry, 22 feet to the west, the band *h* is represented by—

		Ft.	In.
h.	Pisolitic limonite with conchoidal fracture	0	5
	Soft pisolitic limonite with rough fracture	0	4
	Oolitic limonite with conchoidal fracture	0	5½

The middle 4-inch band, therefore, dies out in a very short distance. In the western part of the quarry, also, the band *d* is represented by a layer, about equally thick, of compact brittle limonite. It is further noticeable in this section that ordinary laterite underlies the pisolitic ore.

An average sample from the band *h* gave on analysis—

Ferric oxide	81·20	= Iron 56·84
Phosphoric acid	1·41	
Sulphuric acid	trace.	
Sulphur	trace.	
Loss on ignition	13·42	
Ignited insoluble residue	1·29	
Alumina, lime and undetermined	2·68	
	100·00	

On the north side of the village 3 feet 4 inches of soft pisolitic limonite, with rough fracture, is exposed, with the base not seen. This afforded—

Ferric oxide	71·72	= Iron 50·20
Loss on ignition	14·68	
Ignited insoluble residue	7·94	
Undetermined (alumina & lime in part)	5·66	
	100·00	

In an old pit half a mile east of Bijori 2 feet of ore of the same kind is exposed.

There are a number of abandoned pits about 300 yards north of the village, in one of which the following section was measured:—

	Ft.	In.
Surface soil	1	6
Soft pisolitic limonite with rough fracture	1	5
Pisolitic limonite with conchoidal fracture	0	1
Soft pisolitic limonite with rough fracture	0	7
Ochreous pisolitic limonite with rough fracture	0	3

	Ft.	In.
Pisolitic limonite with conchoidal fracture; the amount of cement between the spherules increasing in amount downwards until the rock passes into highly ferruginous sandstone	0	7 to 8
Soft pisolitic limonite with rough fracture	0	6
Friable ferruginous sandstone with some thin irregular hard layers, seen	1	6

Majhgaon. About half a mile south-west of Majhgaon, some ferruginous beds are very imperfectly seen in a nalla.

	Ft.	In.
Pisolitic limonite with conchoidal fracture, not less than . .	1	6?
Arenaceous semi-ochreous hematite, in beds of irregular thickness, seen	4	0

The lower beds are considerably contorted on a small scale.

On the south-west side of the village, in an old pit, about 2 feet of oolitic limonite, mostly of the soft variety, underlies some 4 feet of lateritic *debris*. The base of the ore is not visible.

Bhadora. Three quarters of a mile south-west of Bhadora there is a group of old pits, in the largest of which the following section was measured:—

	Ft.	In.
Surface soil, &c.	8	0
Bed of earthy limonite, with faint plant impressions . . .	0	10
Lithomargic clay	8	0
Oolitic limonite, softer and less highly ferruginous than that below	2	0
Oolitic limonite, rather soft and breaking with rough fracture, seen	1	0

Summarizing the preceding sections, we find the thicknesses of ore actually seen, to be as follows:—

	Pisolitic limonite with conchoidal fracture. Ft. In.	Pisolitic limonite with rough fracture. Ft. In.	Non-pisolitic limonite. Ft. In.	Hematitic ore. Ft. In.	TOTAL. Ft. In.
¼ mile S. 15° W. from Bijori	1 2	4 2	...	...	5 4
1 mile south of Bijori	1 3	3 7	...	...	4 10
North side of Bijori	...	3 4	...	...	3 4
½ mile east of Bijori	...	2 0	...	...	2 0
300 yards north of Bijori	0 8	2 9	...	...	3 5
½ mile south-west of Majhgaon . . .	1 6?	...	...	4 0	5 6?
South-west side of Majhgaon	...	2 0	...	...	2 0
¾ mile south-west of Bhadora	...	3 0	0 10	...	3 10

In the sections which are best seen there is about 5 feet of ore. In the others either a portion of the ore has been denuded away from the top, or the lowest beds are not visible.

With reference to the important question whether the iron-bearing strata are continuous throughout the area over which the pits above noticed are scattered, it would be perhaps rash to express an unqualified opinion. The strata are most obscurely seen, being rarely visible except in the old pits, and seldom in them even except by clearing out the rubbish, by which they are more or less choked up. But I am certainly strongly inclined to believe that the ore will be found to occur continuously at the same horizon, although the details of the section may vary in different localities. Some of the sections given above show slight differences within a few yards even, but those in which the rocks are best seen agree in there being a foot or so of limonite with conchoidal fracture, covered by a thicker band of the softer kind of ore.

The map scarcely indicates the form of the ground correctly. There is low ground, occupied by alluvium, on the borders of the streams, sloping gently upward to more elevated ground, where the surface rock is laterite, rather than definite hills and valleys. The ore beds generally occur near the foot of the lateritic slope, a little above the level of the alluvium. They have probably, therefore, been denuded away from some, at least, of the alluvial hollows. But these hollows occupy a far less area than the lateritic ground. In the latter I believe the ore will be found continuously; at or close to the surface in the lower ground, and obtainable by open workings, but in the more elevated tracts probably beneath such a depth of overburden as to necessitate shallow mines. The amount of ore must be very large. A continuous bed of even one yard only would contain more than eight million tons to a square mile.

About a mile north of Emelia there are two quarries about 100 yards apart. That to the north was worked last year, and a considerable heap of ore was stacked at the time of my visit. The section includes—

Emelia.

	Ft.	In.
Surface soil	0	2
Highly ferruginous sandstone	1	8
Disintegrated ordinary laterite	1	8
Pisolitic iron ore, seen	4	0

The floor of the quarry is on the ore, so that the total thickness of the latter is not apparent. The strata dip about N. N. W. at 5°. The ore is somewhat different to any that I have seen elsewhere. It consists of spherules of limonite (having an onion-like structure, and ranging up to an inch, or even more, in diameter, but usually not exceeding half an inch) which are embedded in a semi-ochreous cement consisting mainly of brown, but partly of red, oxide of iron. Most of the spherules on the surfaces of fracture remain unbroken, being torn out of their sockets on one side.

In the other quarry the same beds are seen less fully.

	Ft.	In.
Surface soil	0	9
Highly ferruginous sandstone	1	0
Disintegrated ordinary laterite	0	5
Pisolitic iron ore, seen	1	3

The ore is similar to that in the first quarry, except that the cement contains more red oxide. Dip north-west at 5°.

The ore in these quarries being on rising ground, and, where it is now exposed at least, close to the surface, is favourably situated for open workings. An average sample from the first-mentioned gave—

Ferric oxide	77·81	= Iron 54·47
Manganese (calculated as Mn_2O_3). with traces of cobalt	1·54	
Phosphoric acid	·82	
Sulphuric acid	traces.	
Sulphur	traces.	
Loss on ignition	13·20	
Ignited insoluble residue	3·27	
Alumina, lime and undetermined	3·36	
	100·00	

On the rising ground about a mile west-south-west of Jhijri several shallow pits have been sunk, but they are now abandoned. Lumps of ore are freely scattered about over the surface, and here and there a thin bed is visible *in situ*. The thickest I saw included 10 inches of pisolitic limonite with conchoidal fracture.

Jhijri.

At the base of an outlying hillock of laterite, about half a mile north-west of Kailwára, there is a band of ore, similar to that near Jhijri, which has a thickness of not less than 20 inches.

Kailwára.

In a nalla, close to Mr. Olpherts' paint mill on the Katni, a mass of somewhat earthy limonite, mixed with red oxide, appears from beneath the alluvium for a distance of about 20 yards. It has an apparent schistose structure and is unlike any lateritic ore that I am acquainted with. On the other hand, it is very improbable that the Bijáwar rocks should appear at the surface, which they could only do by very peculiar faulting, so that I feel uncertain as to the relations of the ore. It afforded—

Murwára.

Ferric oxide	75·23	= Iron 52·66
Loss on ignition	9·02	
Ignited insoluble residue	11·08	
Undetermined (alumina and lime in part)	4·67	
	100·00	

The Kanhwára hills (6 miles north-east of Murwára) form a level plateau bounded by a sharply defined escarpment. The surface rock on top is ordinary laterite, while bands of rich iron ore outcrop along the face of the slope.

Kanhwára hills.

Pisolitic limonite, in great part of the kind with conchoidal fracture, forms a strong band at the top of the escarpment a quarter of a mile W. 20° N. of Pilongi. There is little or no overburden on it.

At the foot of the ghát, half a mile N. 20° W. of Piprehta, a bed of similar ore not *less* than 2 feet thick is visible.

Not far from the top of the scarp above Piprehta there is a strong band of the same kind of ore. There appears to be another lower down, but the section is obscurely seen.

On the slope of the projecting spur, a quarter of a mile south-east of Piprehta, there are some old pits. In one of them the following section was measured:—

	Ft.	In.
Pisolitic limonite, mainly of the kind with conchoidal fracture, in part somewhat ochreous, seen	2	10
Coarse ferruginous sandstone	1	6
Compact, or slightly ochreous, limonite	0	2
Do. red oxide of iron	0	3
Lithomargic clay, seen	1	6

there being 3 feet 3 inches of ore, with the top of the main band missing through denudation. The ore is 15 feet (vertically) below the top of the hill, which is about 70 yards to the north—

A sample from the main seam yielded on analysis:—

Ferric oxide	82·18	= Iron 57·52
Phosphoric acid	·76	
Sulphuric acid	trace	
Sulphur	traces	
Loss on ignition	13·89	
Ignited insoluble residue	1·57	
Alumina, lime and undetermined	1·60	
	100·00	

It will be noticed that this, as well as the other lateritic ores analysed, contains a much higher percentage of phosphorus than the hematites. In the latter the phosphoric acid ranges from ·10 to ·27 per cent.; in the former from ·76 to 1·41 per cent.

At the foot of the hill, below the pits just mentioned, there is a strong band of oolitic and pisolitic limonite with conchoidal fracture.

To the north-west of Kamtarra (a village 1 mile south of Mohári) there are some old pits 25 feet above the foot of the escarpment, which is 70 feet high. The ore is pisolitic limonite with conchoidal fracture, and is not *less* than 12 inches thick. There seems to be more than one band of ore besides that in the pits, but the section is very obscure. Large quantities of loose ore are strewn on the hill-side at different levels.

Just west of Mohári the hill is capped, with no overburden, by 2 feet 4 inches of oolitic limonite with conchoidal fracture. There are some old pits here, and others about half way down the hill.

In the nalla just north of Mohári there is—

	Ft.	In.
Oolitic limonite with conchoidal fracture, seen	0	9
Slightly arenaceous limonite, in thinnish beds containing plant impressions	0	9
Ferruginous sandstone, seen	1	6

Near the bottom of the ghát, half a mile north-west of Mohári, there is a band of pisolitic limonite with conchoidal fracture, seemingly about 2 feet thick. Higher up there is another strong band of similar ore.

On the slope above Kanhwára 2 feet 6 inches of same kind of ore, but somewhat ochreous in part, outcrops in one place.

About half a mile south of Kanhwára the surface rock, at some little distance from the foot of the escarpment, is pisolitic limonite with conchoidal fracture.

On comparing the above sections it will be seen that there is one band of ore near the top of the escarpment, another at the foot of it, and a third in an intermediate position. The thicknesses, in as far as I was able to ascertain them, were—

	Top seam.	*Middle seam.*	*Bottom seam.*
¼ Mile W. 20° N. of Pilongi	Strong band	...	...
¼ „ N. 20° W. of Piprehta	...	...	Not less than 2 feet.
Piprehta	Strong band	?	...
¼ Mile south-east of Piprehta	Not less than 3 feet 3 inches.	...	Strong band.
North-west of Kamtarra	...	Not less than 1 foot.	...
West of Mohári	Not less than 2 feet 4 inches.	?	...
North of Mohári	...	...	Not less than 1 foot 6 inches.
North-west of Mohári	...	Strong band	2 feet ?
Kanhwára	...	2 feet 6 inches	...
South of Kanhwára	...	...	?

It is, I think, tolerably safe to estimate the average thicknesses of the seams at—

	Ft.	In.
Top seam	2	6
Middle seam	2	0
Bottom seam	2	0

The area of the plateau west of Mohári being about two and a half square miles, there would be in the—

Top seam	19 million tons of ore.
Middle seam	15 „ „
Bottom seam	15 „ „

A large amount of ore from the top seam is available by open workings with free drainage in places where, as in some of the localities noticed above, it occurs at the very top of the escarpment with little or no overburden. A considerable quantity could also be got from the bottom seam, in the same way, in places where it extends into the plain at the foot of the slope. The great mass of ore from the two lower seams, however, and some probably from the top one, could only be obtained by mining. But mining in horizontal strata at such insignificant depths would be of the simplest kind, an immense quantity of ore being within reach by adits driven in from the face of the escarpment.

In the above estimate no account has been taken of the Kanhwára hills east of Mohári, where there can be little doubt ore exists in equal abundance.

A considerable proportion of the ordinary laterite contains a high percentage of iron, and in countries less favoured than that under discussion would be looked on as a valuable ore. As a case in point, I may mention the hillock near Kailwára previously alluded to. It is about 40 feet high, and formed of rock laterite of a common type. A carefully chosen average sample yielded—

Ordinary laterite as ore.

Ferric oxide	63·27	= Iron 44·29
Loss on ignition	10·48	
Ignited insoluble residue	19·36	
Undetermined (mainly alumina and lime)	6·89	
	100·00	

I ought not to conclude these notes on the iron ores of Jabalpur without saying that they do not profess to give an account of every locality in which such mineral resources are to be found. Iron is, indeed, well known to occur in places which I have not visited—at Gangai, for instance, near the marble rocks, and the Majhauli hills, west of Sehora. Such ores, however, are, from their position, obviously out of count in connection with the Umeria coal. In the localities I have described, there is a practically unlimited supply of high-class brown, red, and manganiferous ores, none of which are more than a few miles distant from the railway. So much being ascertained, it would be useless, at any rate until the question of working the ores takes a more definite form than at present, to spend time in the examination of the more remote and less important localities.

Scope of notes.

FLUXES.

The most important member of the Lower Vindhyan series, and that possessing the greatest constancy in the section, is a band of limestone some hundreds of feet in thickness. Constituting, as it does, nearly the highest subdivision of the series, and generally dipping towards the north at moderate angles, it occupies the lower portion of the Kymore escarpment (beneath the sandstones of the upper series), or a belt of country, of varying width, immediately to the south. In this position it extends from near Sasserám to Bijerághogarh, a distance of some 200 miles. In the neighbourhood of the latter town the outcrop is exceptionally wide, covering a breadth of more than 3 miles. A little west of Bijerághogarh, however, the alluvium begins to encroach, the limestone outcrop rapidly narrows, and near the village of Kachgaon finally disappears beneath the more recent deposits[1]. But it is practically certain that, although concealed, the limestone forms a continuous fringe, bordering the Upper Vindhyan rocks, from Kachgaon towards the south-west, and then eastwards again to Murwára. In the latter position there are numerous quarries sunk through the alluvium.

Lower Vindhyan limestone.

These excavations are in a line running north and south from just south of the town to the base of Murwára Hill Station. With one exception they appear to be all very nearly on one strike. The depth of overburden in the different

[1] The narrow band, colored blue on the map, to the westward of Kachgaon, is of shale, which occupies a position between the limestone and the Upper Vindhyan rocks above.

quarries varies from 10 to 25 feet, except in the most southern of the line, where it is less than 5. It consists of clay, with Lower Vindhyan shales and inferior shaly limestone, which overlie the band that is worked. The latter consists of grey limestone in beds of rather small thickness, averaging say 2 to 5 inches. A carefully chosen average sample gave—

Carbonate of lime	94·65
„ of magnesia (by diff.)	2·98
„ of iron	·58
Phosphoric acid	traces
Sulphuric acid	0·00
Sulphur	traces[1]
Ignited insoluble residue	1·79
	100·00

—a result which shows the stone to be eminently suitable as a flux.

The band of superior limestone (above and below which is inferior stone) is only some 10 feet thick, and as it dips (towards the west) at 15°—20°, it cannot be followed towards the deep for any distance, the overburden even at the outcrop being excessive. The amount of stone therefore obtainable from the present quarries is limited. The outcrop of the whole band of limestone, however (which, as I have said, is some hundreds of feet thick in the Son Valley), probably extends for a considerable distance eastwards of the quarries beneath the laterite and alluvium, and many other beds of good stone are probably concealed in that position. (There is indeed one excavation, some 130 yards east of the others, which has struck limestone, but of an inferior kind.) It is very doubtful, however, whether the more recent deposits are not too thick to allow of such being worked, even if found. A well in Mr. Olpherts' compound, a few hundred yards east of the line of quarries, was sunk through 90 feet of clay without striking rock.

In the event, then, of iron works on a large scale being started at Murwára, I think it is not impossible that, sooner or later, the supply of limestone on the spot will fail. In this case search should be made a little south of where the railway passes through the Kymore hills (west of Ponchi). It is quite possible that the limestone is to be found there beneath a less depth of overburden than at Murwára, and a few shallow wells would be sufficient to settle whether it is or not. If not, perhaps the best plan would be to construct a tramway from Murwára to the limestone area west of Bijerághoghar, or to the latter town itself. Limestone is to be had there in unlimited quantity at the surface of the ground. The tramway, therefore, besides serving to bring in iron ore from the rich deposits of the Kanhwára hills, and flux for smelting purposes, could supply lime-works on any required scale with stone, probably at a cheaper rate than it can be had now at Murwára, as the expense of removing such a mass of overburden would be avoided. As the Murwára[2] lime is now exported as far even as Calcutta, a market would doubtless be found for a large supply, if deliverable at a sufficiently low rate. A certain amount of passenger and ordinary goods traffic would also, no doubt, be obtainable for such a tramway as a feeder of the East Indian Rail-

[1] ·004.

[2] Or Katni. Murwára is the name of the town, Katni that of the adjoining railway station.

way. As the country is nearly level, with only one stream of any size to cross, there would be no difficulty in construction.

Lameta limestone.

There is an unlimited supply of limestone to be obtained from the lameta beds. Besides the fact, however, that these rocks do not approach the railway anywhere north of Jabalpur, the stone is markedly inferior to that of Murwára. An average sample, taken from several heaps collected for burning near Jabalpur, contained 21·38 per cent. of residue insoluble in hydrochloric acid, the remainder being carbonate of lime, with trifling quantities of magnesia and iron.

Aluminous laterite.

A pisolitic variety of laterite, containing, besides iron, a large proportion of alumina, occurs abundantly in the hills south of Murwára. If an aluminous flux should be required for smelting some of the hematite ores, the rock in question might perhaps be found useful.

DOLOMITE.

The occurrence of manganiferous iron ore, available for the production of spiegeleisen, would probably lead to Bessemer steel-making being included in any scheme for utilising the Jabalpur ores. If the basic process were adopted, dolomite for lining the converters would be required. The rock occurs in great abundance in the district, and, although very unequal in quality, can be obtained, by a little selection, of great purity.

Marble rocks.

The well-known 'marble rocks,' which are situated about 2 miles from Mirganj station on the Great Indian Peninsular Railway (11 miles from Jabalpur and 68 from Murwára), are dolomitic throughout. The rock has a saccharine texture, and is mainly of a pure white colour, although here and there it has a grey, yellow, or pink tinge. The bedding, as a rule, is not very thick, and in places it is quite thin, the rock verging towards a dolomitic schist. The greater portion of the dolomite contains disseminated crystals of tremolite, and very often irregular strangulated layers of quartz parallel to the bedding. But rock free from visible impurity is to be obtained without any difficulty. A sample of such, of a pure white colour, and obtained from different spots, yielded—

Carbonate of lime	55·48
" " magnesia (by diff.)	43·55
" " iron	·36
Ignited insoluble residue	·61
	100·00

This is a very close approximation to normal dolomite, which contains 54·35 and 45·65 per cent. of carbonate of lime and magnesia respectively.

Near Sleemanabad.

Dolomite of a somewhat less pure variety also occurs largely in the neighbourhood of Sleemanabad. It is mostly grey, with occasional cherty and quartzose bands, but rock free from visible impurity can easily be got by selection. A sample taken from the side of the

railway between Dharoli and Deori (2 miles from Sleemanabad station and 20 from Murwára) gave—

Carbonate of lime	52·45
„ „ magnesia (by diff.)	38·22
„ „ iron	2·76
Ignited insoluble residue	6·57
	100·00

The same band of rock is also found close to the Sleemanabad station.

FIRECLAY.

Jabalpur.

Firebricks have been made in the Jabalpur jail from clay obtained from the Upper Gondwána beds, in the neighbourhood of Jackson's hotel. Last year I made some trial of their infusibility on a small scale. Three sharp-edged fragments, together with three similar fragments of a Scotch firebrick, from Kilmarnock, were placed in a covered crucible, and exposed for an hour to a dazzling white heat in a Fletcher's injector gas furnace. After cooling it was found that the edges of none of the fragments showed even incipient signs of fusion. The fragments of both bricks had acquired a slight glaze on the parts forming portions of the original surfaces, and when broken were found to have become extremely hard (so as to resist the point of a knife), somewhat porous, and the fracture semi-vitreous looking. The Jabalpur brick, before heating, had a smoother fracture than the Scotch one, and was much softer and more easily broken. After heating, however, both seemed to be equally hard.

Amdari.

Bábu Hira Lál, of the Geological Survey, recently forwarded some clay, similar in appearance to that from which the Jabalpur bricks were made, which he found in the Upper Gondwána strata in the hill west of Amdari, a village 14 miles south-west of Chandia. He states that the clay occurs in considerable quantity. It is a white indurated kind, breaking with a semi-conchoidal fracture when dry. When powered moderately finely[1], it yielded a highly plastic mass with water. From this small bricks with sharp square edges were made, measuring $1\frac{1}{2}'' + \frac{1}{2}'' + \frac{1}{4}''$. Similar bricks were made from fireclay from Glenboig and Garnkirk (Scotland) and from Ràniganj. One of each was enclosed in a covered crucible, with one end resting on the bottom, and the other touching the side. After exposure for an hour to a dazzling white heat in an injector furnace[2], the edges of the Amdari brick were only slightly rounded, but the brick had softened sufficiently to allow it to bend somewhat, until partially supported by the side of the crucible. It had not contracted in a marked degree. The Glenboig and Garnkirk bricks remained with perfectly sharp edges and contracted very slightly; the former showed no trace of bending, while the latter was bent in a very slight degree. The Ràniganj brick had the edges completely rounded, and was reduced to a semi-fused condition.

[1] Sifted through a sieve of 38 holes to the linear inch.

[2] The temperature was sufficiently high to soften the cover of a crucible from the Battersea works, and allow it to sagg downwards.

Some of the powdered Amdari clay was subsequently washed by suspension in water, dried, repowdered and sifted, and made into bricks of the same kind, which were similarly heated. The edges were very slightly rounded, and the bricks bent somewhat from their own weight, but decidedly less than that made from unwashed clay.

Although the clay, then, showed itself to be inferior to Scotch clay, good fire-bricks could probably be made from it, especially if washed. Similar clay is doubtless to be found elsewhere in the Upper Gondwána area, and one may expect the coal measures of Umeria to contain fireclays like those of Rániganj and other coal fields.

MURWÁRA AS A SITE FOR IRON-WORKS.

In the preceding remarks I have more than once alluded to Murwára as a site for future iron-works. The advantages of the position are not far to seek. The two primary conditions in selecting a site are firstly, that there shall be an ample supply of water, and secondly, that the spot shall be on the line of railway. Now, between Gosulpur, in the neighbourhood of the most important hematite and manganiferous deposits, and Umeria, *viâ* Murwára, the East Indian Railway and the projected line to Umeria only cross three streams of any size, namely, the Heran, south of Sehora; the Katni, at Murwára; and the Máhanaddi, near Chandia. The first of these is obviously too far away from the coal-field. The Máhanaddi is within a comparatively short distance of the coal, which forms the heaviest individual item of haulage, but not only would the ore and flux have to be taken from near, or beyond, Murwára to the Máhanaddi, but all the iron produced would have to be carried from the Máhanaddi to Murwára. Roughly speaking, there would be the haulage of ore + flux + iron *versus* the haulage of coal[1].

Murwára, as will have been seen, occupies a central position with reference to the different mineral products required. It is actually on limestone, and within less than 15 miles of an unlimited supply of the same mineral to the north-east. It is in the immediate neighbourhood of the lateritic brown ores, and about equally distant from the Umeria coal-field to the south-east, and the hematite and manganiferous ores to the south-west, while dolomite is to be had within 20 miles by railway. The Katni, which flows past Murwára, is a stream with a drainage area of 230 square miles above the town, and there is an abundant supply of water throughout the year[2].

[1] If the new line were continued to Belaspur a certain quantity of iron would find its way to the south-east, but the amount would probably be a small proportion of the total made.

[2] It appears from data kindly supplied to me by Mr. V. Pont, Resident Engineer of the East Indian Railway at Jabalpur, that in April last year, when the stream would be almost at its lowest, there was a flow of 996 cubic feet per minute.

A magnificent sheet of water could be formed by throwing a dam across the gorge, through which the Katni flows just west of Murwára, and a sufficient head of water perhaps obtained to work heavy machinery; to ascertain the exact fall obtainable would require actual levelling. The reservoir, however, could unfortunately only be made at the expense of submerging a large area of cultivated land.

On Lateritic *and other* Manganese Ore *occurring at* Gosulpur, Jabalpur District, *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

In a previous volume of the Records[1] some account is given of the manganese ore at Gosulpur, which was visited by the Superintendent of the Geological Survey in 1879. The sections then available for examination were very poor indeed, but, judging from which could be seen, Mr. Medlicott thought that a large supply of the ore could probably be depended on. The following year a shaft was sunk with a view of testing the richness of the deposit. When this had reached a depth of 20 feet, the engineer in charge reported "that all trace of the ore was lost at a depth of 9 feet from the surface, at which depth a yellow subsoil, resembling ochre, was entered; that about 1½ cubic feet of ore were obtained, and even this small quantity of rather an inferior quality; that in consequence I recommended and discontinued operations." As this discouraging result was at variance with the hope previously entertained of a considerable supply, I was directed to take the opportunity, while in the neighbourhood recently, of visiting the locality and seeing how the discrepancy was to be explained.

The shaft is dug on the site of the pre-existing holes examined by Mr. Medlicott, from which the ore had been extracted for use in glass-making at Murwára and elsewhere. The section comprises—

	Feet.
a. Laterite	4 to 5.
b. Manganese ore	2 „ 2½.
c. Laterite containing some nodules of manganese ore, about	6
d. Distintegrated quartz schist dipping at a high angle (to bottom of shaft)	7

The manganese ore *b*, which, as mentioned in the previous notice[2], is pyrolusite mixed with some psilomelane, occurs in the form of irregular spongy nodules varying in size from a fraction of an inch to several inches diameter, and averaging perhaps half an inch to 1 or 2 inches. These seem to constitute an irregular layer, which is 2 feet thick, or rather more, at the shaft. It is exposed in two or three other places within a length of 20 feet. The level varies somewhat even in this short distance, and, as pointed out by Mr Medlicott, the ore found in the village well, 120 yards to the east, is at a lower level than that at the shaft. This difference is, I think, to be ascribed to the laterite (including the ore) having been deposited on an irregularly denuded floor of Bijáwar rocks.

There is little or no laterite of the ordinary (ferruginous) type included in the manganese stratum, and the separation between this stratum and the laterite above is tolerably well defined; that between the manganese and the laterite below is not so well marked, the laterite containing occasional nodules of pyrolusite through it. The laterite above and below the ore looks somewhat like the detrital variety, but experience elsewhere has led me to believe that the rock laterite[3] has a tendency to disintegrate into a mass of irregular nodular fragments, which bear

[1] Vol. XII, p. 99.

[2] *Ibid*, p. 100.

[3] By 'rock laterite' I mean the first form of laterite mentioned on page 117. The term is no doubt open to criticism, but is convenient and serves to avoid circumlocution.

a very close resemblance to the detrital form. Taking into account that no distinctly foreign matter is visible in the rock in question; that undoubted rock laterite occurs close by; and that the manganese ore is pyrolusite, not psilomelane (a point to which I shall allude again), I do not think there can be any reasonable doubt that the laterite, inclusive of the ore, is rock laterite, not detrital. Such is the view which Mr. Medlicott also took: "This laterite is of the older type; at least in the exposed sections I could not detect any palpable *debris*, which generally characterises the secondary or detrital laterite. It is therefore presumable that the lumps of ore are in rate, and that the manganese is an integral component of the laterite in this position."[1]

With reference to the original source from which the manganese was derived, it is I think scarcely open to doubt that it is to be sought in the strong band of manganiferous micaceous iron which outcrops along the southern side of the Lora range and again at Gosalpur[2]. But, as I said in the preceding paper, the manganese in this ore occurs mainly, if not entirely, in the form of psilomelane, while the manganese of the laterite is mainly pyrolusite. The latter, therefore, cannot be the result of mere mechanical degradation and transport, unless it be supposed that the nodules in which the ore occurs are pebbles, originally of one mineral which has subsequently been changed into another. This mode of origin is rendered very unlikely by the absence of any other recognisable debris in the manganese stratum.

If the latter be not a mechanical deposit, it must be a chemical one. Carbonate of manganese being, like carbonate of iron, soluble in water holding carbonic acid in solution, the former metal is capable of being leached out and re-deposited in the same, or nearly the same, way as the latter[3]. During the deposition of the main stratum of manganese ore, the water appears to have held little but manganous carbonate in solution, while at the time the laterite below was formed, ferrous carbonate was the chief substance dissolved, but with some manganous salt, the manganese subsequently separating itself into nodules by segregatory action. Specimens may be obtained consisting in part of ordinary laterite, and partly of manganese oxide.

The occurrence of this manganese laterite, interbedded with ordinary ferruginous laterite, furnishes, I think, strong evidence in favour of the view as to the origin of the latter which I have advocated in a former paper[4], namely, that laterite is (in as far as the iron is concerned) a chemical deposit due to the leaching out and redeposition of iron through the agency of decaying vegetation and the carbonic acid produced by its decomposition. I of course am speaking of the first only of the three forms of laterite which I believe are now generally recognised, *viz*:—

1st.—Laterite due to deposition, and excluding the *3rd* form.

2nd.—Laterite due to the alteration of other rocks *in situ*[5].

[1] Vol. XII, page 99.
[2] Page 102.
[3] *Vide* Vol. XIV, page 145.
[4] *Ibid*, page 139.
[5] Some examples of this form are noticed in the preceding paper, pages 97, 98.

3rd.—Detrital laterite due to the denudation and redeposition of
2nd form.

With reference to the amount of manganese ore obtainable, it is no
form any decided opinion. I think, however, that there is a fair cha
layer being somewhat extensive, although very likely subject to much i
in level and the amount of overburden covering it, and perhaps in thic
When there is a demand for the mineral, the bed might be followed from t
diggings, and the superincumbent laterit utilised for road metal on th
road which passes close by.

It will have been seen that the reason why so little ore was obtained
shaft was that the latter passes through the manganese stratum into qu
below it. The shaft, indeed, merely exposed the thickness of the bed, b
nothing as to its lateral extension.

In the preceding paper I have pointed out that a considerable q
psilomelane occurs with the manganiferous micaceous iron at Gosulpur
latter were worked in connection with iron-making, the psilomelane
raised at the same time, and available as an ore of manganese. On
yielded 83·20 per cent. of available peroxide, or about the same amou
lateritic pyrolusite. From both sources combined it may be reasonab
that a considerable supply of ore will be procurable when there is a de
it.

Further notes on the Umaria Coal-field (*South Rewah Gondwana Basin*),
W. H. Hughes, A.R.S.M., F.G.S., *Geological Survey of India*

In my notes of last year on the Umaria coal-field were embodied th
results inferable from the evidence afforded by the preliminary ex
carried out under the management of the Rewah State: that coal
occurred in abundance; that it lay at a shallow depth from the sur
a proved area of 1½ square miles; that it thickened to the deep; that the
was low and advantageous for working; and that the quality of the co
outcrop was encouraging.

The promise was a fair one, and from the exceptionally commanding
phical position of the field it required small advocacy to show that if th
ations based on the introductory enquiries were confirmed, a splendid n
coal had been established. I am happy to say that Captain Barr, the
Agent of Rewah, has keenly appreciated the exigencies of the case, and
ther sanction has been obtained for carrying out such trials as shall set at
apprehensions that prudence may give rise to.

I confess that I have little or no misgiving as to the worth of the Um
the adjacent Johilla fields, and I have belief enough in my opinion
it expression. But I admit the necessity of verification; and, in view
important issues dependent upon the true practical estimate of these
strongly commend the course that had been suggested of reducing to its na
limits the margin of uncertainty regarding the nature, quality, and perma
their seams.

To achieve this object it was determined that the coal should be approached under the ordinary conditions of approved mining. There were two plans open for adoption, either to drive an incline from the outcrop, or to sink a shaft to the seam. The second method was preferred, as being in every sense more workman-like, and as affording more scope for efficiently dealing with an influx of water; and on the 11th March 1883, a pit of 10 feet internal diameter was commenced under the charge of Mr. Thomas Forster, M.E.

Shaft determined upon.

The position of the pit is near No. 8 bore-hole, where Mr. Stewart struck coal at 93 feet from the surface and recorded the thickness of the seam as 10 feet. I had a strong wish to go further to the deep towards No. 9 bore-hole, but I was deterred by the dread of water, and the possibly heavy outlay that would have to be incurred for pumping machinery.

Position of pit. Record of No. 8 bore-hole.

In an untried field it is always impossible to gauge the water difficulty, and I selected the spot for the trial shaft where I anticipated the least amount of inconvenience on this score. The choice has been up to the present justified by the results, for though the shaft is 40 feet deep one workman occasionally bailing suffices to keep it dry. Should the pleasant expectation that this fact gives rise to be strengthened by further experience, I would certainly recommend another pit near No. 9 bore-hole being put down. In the future development of the field, it would act as a ventilation channel; and in the initiatory stage it would yield another point where the quality of the coal might be judged.

Water.

According to the journals of last year, two seams measuring respectively 10 feet and 6 feet were passed through in No. 9 boring, and I remember that the coal brought up in the sludger was very clean and bright. The section of the hole is as follows:—

No. 9 bore-hole.

No. 9 bore-hole—

1.	Black surface soil	1′ 0″
2.	Brown sandy soil	7′ 0″
3.	Brown sandstone	9′ 0″
4.	Red sandstone	30′ 0″
5.	Carbonaceous shaly sandstone	8′ 0″
6.	Carbonaceous sandstone	13′ 0″
7.	*Coal*	*2′ 0″*
8.	Carbonaceous shale	1′ 0″
9.	Carbonaceous shaly sandstone	3′ 0″
10.	*Coal*	*10′ 0″*
11.	Carbonaceous shaly sandstone	3′ 0″
12.	Carbonaceous shale	1′ 0″
13.	*Coal*	*2′ 0″*
14.	Carabonaceous shale	1′ 0″
15.	*Coal*	*6′ 0″*
	TOTAL	92′ 0″

As the trial shaft has not yet reached coal, I have not much to comm upon; but I would explain that a more favourable record of labour could been shown had local skilled artizans been available, and had not vexa delays occurred in procuring and transporting the mining plant, and in gath together the necessary building materials. It has also been a misfortune Mr. Forster was continuously indisposed, and that his illness at one time w aggravated that he had to go to Jabalpur for European medical advice. withstanding all these drawbacks, very fair progress has been made; and pared with the experience during the early days in the Wardha Valley coal- there is considerable room for congratulation.

The main operations are those in connection with the shaft and the work that will be extended from it; but in order to gain some immediate inform respecting the seam, and at the same time win a little coal for night fires, sn fires, limestone burning and brick burning, a narrow 6-feet incline was dı down to the deep from the quarry made last year. It been advanced a distance of 20 yards. Throughout length the seam retains nearly the thickness that it has at the outcrop, and comparison I give the sections that are seen at the extreme ends of the inclir

Incline 6' wide.

		Outcrop (1882).	Heading (1883).
(*a*)	Coal hard	6"	10"
(*b*)	Stony band	1"	1½"
(*c*)	Coal bright	6"	7"
(*d*)	„ hard	7"	6"
(*e*)	„ bright	6"	6"
(*f*)	„ hard	4"	1½"
(*g*)	Stone band	2"	½"
(*h*)	Coal hard	2' 0"	2' 0'
		4' 8"	4' 8¼"

Mr. Forster says that the coal works easily, and that there is a thin bar soft shale under the bottom of the seam which will litate pricking, and so reduce very materially the am of waste. The roof is an excellent one, and not a si stick of timber has been required to support it. This is a most favourable fea in the estimation of the seam, for when a roof is bad the expenditure unde heading of timber forms a considerable item. With respect to the quality bottom 2 feet and the bright coals are excellent; but the hard band lettered and which varies in thickness, would have to be picked out, as it clinkers easily. The addition to the cost of getting the coal that this picking w entail might be set down at quarter of an anna a ton.

Mr. Forster's opinion of the seam.

The operations are not sufficiently advanced yet to yield facts on which to conclusive inferences; but I may venture to say that the aspect of affair to the present is *not* discouraging.

The amount so far expended on the works and establishment is Rs. 8, and a further sum of Rs. 10,000 has been allowed for completion of the enquiry, including the raising of tons of coal.

Expenditure.

At a small additional cost the Johilla valley seams can be tested, as the necessary machinery and other plant will be at hand, and trained men will be available. I would strongly urge that these seams be not overlooked, and a less elaborate method of procedure to that adopted in the Umaria field may be followed.

Johilla seams.

A period of six or seven months ought to be quite time enough in which to carry out the plans now in hand, and by the end of the next working season, I trust we shall be able to give practical answers to all practical questions.

UMARIA,
23rd May 1882.

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Coal from Kywaising, Henzada, Burma.

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Auriferous quartz from various localities in the Nilgiri district, Madras.

R. BROUGH SMYTH.

Tinstone from Mt. Bischof, Tasmania.

W. G. OLPHERTS.

Heulandite from Dumbartonshire, and two concretions from the Permian limestone of Sunderland.

DR. G. WATT.

Red hematite, micaceous iron, and limonite from the Jabalpur district, with a bloom of iron smelted from each ore; also pyrolusite from Gosulpur.

W. G. OLPHERTS.

A slab of Bhanrer sandstone with dendritic markings, from near Satna, E. I. R.

G. PEDDIE.

Opal in a ferruginous matrix, from Queensland.

G. NEVILL.

ADDITIONS TO THE LIBRARY.

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BRONN'S.—Klassen und Ordnungen des Thier-Reichs.
Band I, Protozoa, lief. 14—19.
Band VI, Abth. III, Reptilien, Lief. 35 (1882), 8vo., Leipzig.

CAPELLINI, G.—Congrès Géologique International. 2me Session, Bologne, 1881, (1882), 8vo., pht., Bologne.

THE AUTHORS

Catalogue of the Jeypore Exhibition for Indian Raw Produce, Arts and Manufactures (1883), 8vo., Calcutta.

THE HONY. SECY.

CHURCH, ARTHUR HERBERT.—Laboratory Guide for Agricultural Students, 5th Edition (1882), 8vo., London.

Titles of Books. *Donors.*

Descriptive Catalogue of Articles exhibited at the Calcutta Exhibition of Indian Art Manufactures, 1882, held at the Indian Museum in January 1882, (1883), flsc., Calcutta.

THE SECRETARY.

DEWALQUE, M. G.—Sur la nouvelle note de M. E. Dupont concernant sa revendication de priorité (1882), 8vo., pht., Bruxelles.

THE AUTHOR.

DUTTON, C. E.—Report on the Geology of the High Plateaus of Utah, with Atlas, (1880), 4to., Washington.

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THE UNITED STATES GEOLOGICAL SURVEY.

April 16th, 1883.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1883. [August.

On the microscopic structure *of some* Dalhousie rocks—*By* COLONEL C. A. MCMAHON, F.G.S. (*With two plates.*)[1]

THE GNEISSOSE GRANITE.

In order to avoid repetition it will be convenient to describe the following sample specimens of the Dalhousie granitic rocks together. An account of their macroscopical and lithological aspect has already been given in my paper on the geology of Dalhousie (*supra* Vol. XV, p. 34).

Specimens described.

No. 1. Porphyritic gneissose granite. Bakrota Upper Mall, Dalhousie.
" 2. Ditto from the same locality.
" 3. Fine-grained granite from the summit of Dainkund.
" 4. Granite from the same locality.
" 5. Another specimen from the same locality.
" 6. Gneissose granite on the road from the church to the brewery, south-west side of the Dalhousie ridge.
" 7. Porphyritic variety on the same road.
" 8. Another porphyritic specimen from the same locality.
" 9. Gneissose granite on the road from the church to the water-works, south-east side of the Dalhousie ridge.
" 10. Another specimen from the same locality.
" 11. Fine-grained granite near Chil on the Dalhousie and Chamba lower road.
" 12. White granite on the same road about two-thirds of the way to Chil.
" 13. Prophyritic variety with very fine-grained matrix, having a superficial resemblance to a felspar porphyry. Between Dalhousie and Chil, on lower road to Chamba.
" 14. A light-coloured gneissose granite from the same locality.
" 15. Gneissose granite in actual contact with the slates on the road to Bakloh (above the slate quarries), Dalhousie.

[1] It is due to Colonel McMahon to state that this paper has been in my hands since the 15th March, and was in type for the May number of the Records, but had to be deferred on account of delay in obtaining the heliogravure copper-plates. This was particularly unfortunate when there is so much discussion going on regarding gneissose granite.—H. B. MEDLICOTT.

All the above specimens are rich in quartz, and, as is usually the case in granites, this mineral polarises with great brilliancy. The polysynthetic structure is extremely prominent, and is very characteristic of the quartz of these rocks.

Dr. Sorby[1] states that "the quartz of *thin foliated* gneiss and mica schist differs from that of granite in having a far less simple optic structure;" * * * "instead of the larger portions of quartz being made up of a few comparatively large crystals, they are frequently composed of very many closely dove-tailed together, as if formed *in situ*." On the following page he goes on to state: "I have been unable to detect anything that would serve to distinguish the quartz of *thick foliated* schists from that of true granite."

An attempt has been made at fig. 1, plate I, to depict the appearance of the quartz, as seen in slice No. I. in polarised light. The quartz is seen to be composed of a number of large crystals and of congeries of microscopic grains suggestive of the roe of a fish. The small grains polarise as brilliantly as the large ones, and they add greatly to the beauty of the slices under the polariscope.

The fish-roe grains for the most part divide large grains of quartz from each other, forming a brilliant setting to them: sometimes this setting is thick, as in my illustration, but at others it is limited to a single line of crystals. Cracks in felspars filled up with these micro-crystals are common, and occasionally irregular branches meander into the interior of large crystals of quartz.

Some specimens of granite collected by me on the Grimsel pass, Switzerland, contain exactly similar fish-roe grains intermixed with larger grains of quartz.

On the whole I do not see sufficient grounds for regarding this polysynthetic structure as affording evidence of the original clastic origin of the Dalhousie rocks. This structure, as seen in these rocks, seems to me rather to suggest that the large grains were the result of slow cooling; whilst the fish-roe micro-grains appear to indicate either a comparatively rapid ending of the process, or conditions of strain towards its termination.

The quartz in all the specimens contain liquid cavities with movable bubbles. They exist in prodigious numbers in some specimens, whilst in others they are sparse; in most, however, they are abundant. Air, or gas, cavities are also present.

There are apparently some stone cavities. These appear to have either deposited a second mineral on cooling, or to have caught up opacite or other similar substance in the act of crystallization. Some of them appear to contain fixed bubbles. These enclosures, however, are so exceedingly minute that they cannot be satisfactorily determined with the highest powers applicable. Some microliths contain internal cavities, running with the length of the microliths for a portion of their length, which undoubtedly indicate shrinkage on cooling.

All the specimens, without exception, contain more or less triclinic felspar. In some it is rather abundant; in others sparse. It appears from its optical characters to be oligoclase.

Eight out of the 15 slices contain typical microcline, and in some of them it is abundant.

[1] Anniversary Address, Q. J. G. S., XXXVI, 48.

Zirkel at pp. 45, 47, of his Microscopical Petrology of the 40th Parallel, desribes the occurrence of a fibrous orthoclase in granite. A similar felspar is very bundant in these rocks. It occurs in all but three of the specimens, the slices ı which it is not present, namely, Nos. 3, 12, and 14, being those in which typical ıicrocline is also absent. In every slice in which typical microcline occurs, the brous felspar is present. It also occurs in three slices in which the typical mineral ; absent. The fibrous appearance is only observable in polarised light, and the elspar in which it occurs seems to me to be a form of microcline. In some an ıcipient cross hatching can be made out; whilst in one, at least, it is distinctly isible in parts of the fibrous structure.

Orthoclase is present in all the slices, though, if the fibrous felspar be included nder the head of microcline, the latter mineral is more abundant than orthoclase. he triclinic felspar (oligoclase) is very subordinate to the orthoclase and microline taken together.

Much of the felspar is very opaque and has a white glistening appearance in eflected light owing to the presence in it of a multitude of extremely minute gas r air cavities. Liquid cavities with movable bubbles also occur here and there ı the felspar.

Some of the felspars are studded with numerous microliths of silvery mica, hich occasionally, in polarised light, impart to the portion of the slice in the eld of the microscope the appearance of graphic granite. Zirkel, in his work on he rocks of the 40th Parallel (p. 46), notes the occurrence of a similar structure ı the granites of Nevada.

Many of the orthoclases and microclines contain the usual intergrowths of lagioclase and occasionally grains of quartz. Some of the microcline exhibits a endency to inter-laminated structure resembling that of perthite, only it is finer rained and less pronounced. The intergrowth of felspar alluded to is quite disnct from the ordinary twinned structure.

All the specimens contain muscovite, and in all but three biotite is present. The ıuscovite polarises in delicate but brilliant colours, and some of it is twinned. ome of this mica contains inclusions in the line of basal cleavage of a substance ıat is absolutely opaque, and black, in transmitted light, and shines with a bright lvery lustre in reflected light.

Muscovite is present in all these slices, not only in good-sized plates and packets, ut in a form for which I propose the name of crypto-crystalline mica. In this orm no definite crystals can be made out, the leaflets, under polarised light, fade nd melt into each other and exhibit no definite shape; whilst no signs of leavage or lamination are visible.

In transmitted light the crypto-crystalline mica varies from a pale buff to a ale grey colour, and has a superficial resemblance to the base of some felsites and ıyolites. In a specimen in my collection, labelled "Banded felsite, Glencoe" (I d not myself collect the hand specimen from which the slice was made), I find precisely similar structure present, along with quartz, and the ordinary felsitic ase of felstones.

The felsitic matrix of felstones is believed to be an intimate mixture of quartz ıd orthoclase; and I suspect, from the appearance of some of my specimens,

tion: the crypto-crystalline structure of the mica now described may be due to an admixture of quartz with the mica.

The crypto-crystalline mica passes imperceptibly into a condition that would require, strictly speaking, the use of the term micro-crystalline, but in the following pages I propose calling it all crypto-crystalline mica.

The crypto-crystalline mica is present in all the slices. It traverses them in every manner: sometimes it is extremely attenuated and drawn out into thin strings: at other times it widens out into comparatively broad expanses. It frequently encloses, or leads up to, crystals of muscovite, and of quartz, and more rarely encloses other minerals. It meanders through some large crystals of felspar; whilst isolated patches of it are caught up in other felspar crystals. In both these last cases it represents, I apprehend, the residuum left after the separation of the constituents of the felspar.

All the slices contain magnetite grains and garnets, but in some of them both the garnets and the magnetite grains are very minute.

Six of the slices, namely, Nos. 3, 4, 7, 11, 12, and 13, contain schorl. It is in a rather fragmentary condition, and is much cracked, the cracks being filled with quartz. In some cases the fragments appear to have floated some little distance from each other.

No. 15, a specimen of the gneissose granite in actual contact with the slates above the slate quarries, is a very interesting and instructive slice, for it exhibits in a typical way what appear to me to be decided indications of fluxion structure consequent on traction. Both the biotite and the crypto-crystalline mica are drawn out into long strings in the direction of the flow. This structure is not confined to the larger bands, which can be discerned with the aid of a pocket lens, but even the microliths of muscovite in the quartz are seen, under the microscope, to point in the same direction, and to be drawn out into long trains or strings.

Even more characteristic are the gas cavities. Some of these are themselves elongated and drawn out in the direction of the flow, and they are arranged in lines pointing in the same direction. Some of the gas cavities have deposited granular matter on cooling.

There are also stone cavities, the longer axes of which point in the direction of the flow.

This slice seems to me to exhibit, as far as a granite can do so, as decided fluxion structure as that to be seen in rhyolites and obsidians.

An attempt to give an idea of the appearance of this slice under the microscope, has been made at fig. 2, plate II, where the bands of crypto-crystalline mica and biotite are represented drawn out into strings.

The quartz, though hyaline in transmitted light, is seen between crossed nicols to consist almost entirely of the fish-roe grains, previously described, drawn out into lines in the direction of the flow. Possibly this structure may depend on strain.

A pseudo fluxion structure is doubtless to be seen in many gneissic rocks, but that above described can alone be attributed, I think, to the action of traction in a rock in motion reduced to a plastic condition by heat.

Another piece of evidence in favour of the conclusion that the fluxion structure observable in the slice under consideration is due to traction, is to be found in the crumpled appearance of some of biotites. I have sketched one in this slice at fig. 4, plate II; a single crystal, one-half of which has been folded over and bent back flat upon the other half. This biotite must, I apprehend, have been crumpled up and folded over on itself after crystallization, but whilst the folia were still in a somewhat pliable condition. I cannot conceive of a contortion of the basal cleavage lines, to the extent represented in the sketch, being produced in any other way. A moderate curvature of the basal cleavage lines is not an uncommon feature in the mica of some rocks, and I can readily understand how this may have been produced, even in the case of mica formed in clastic rocks by an epigenital process; for such mica, formed *in situ* in the spaces between the fragments of clastic origin, might often be cramped at the time of formation, and its symmetry interfered with, from want of space for its perfect development; but I do not think a mica could, from this cause, be completely doubled up in the manner represented in the illustration.

The basal cleavage lines of the mica enclosed in the long ropy strings of crypto-crystalline mica are usually at a slight angle to the direction of the flow, as represented at fig. 5, plate II, the direction of the flow being east and west. The outer edge of these biotites is usually covered with dark fluffy matter.

The foliation of the slaty portion of No. 15 is parallel to the line of fluxion in the granite.

Rocks next the gneissose granite.

Considering how important a thorough knowledge of the Dalhousie rocks is in determining questions of local geology, I propose to give a brief separate description of each of the remaining slices.

No. 16.—Junction of an intrusive vein, 3 or 4 yards wide, and the slate into which it is intruded, close to the main mass of the gneissose granite on the road to Mamul, Dalhousie. The actual junction of the two rocks is seen both in the hand specimen and in the slice.

M.—This slice shows the junction of the two rocks perfectly. The granitic rock possesses the characteristics of some of those already described, being distinctly gneissoid, whilst foliation has been set up in the slate. The structure of the slate corresponds closely to No. 19, described further on.

The slate contains numerous crystals of schorl which do not extend into the granitic rock; whilst the latter contains many small garnets, a mineral not visible in the slate.

There are several points of difference to be noticed between the silvery mica of the granitic rock and that of the slate. The silvery mica of the granite is pure looking; is in large leaflets; its basal cleavage is very perfect; and the cleavage lines are close together; whilst twinning is not uncommon. The silvery mica in the slate, on the other hand, contains numerous inclusions indicating an imperfect separation between the several constituents of the slate; it is in small leaflets; its basal cleavage is imperfect; and the cleavage lines are sparse; whilst there are no indications of twinning.

The granitic rock gives several indications of fluxion structure. The cryptocrystalline mica forms long curving streams in the ground mass, meandering about as an Indian river in its sandy bed during the dry months. In some places these streams approach each other and join; at others they make wide sweeps and diverge considerably. The curves are sometimes gentle, but at others they are rather sharp and have a wide radius. Sometimes the streams are broad; at others they are split up into innumerable narrow meandering rivulets. The dark mica also forms ropy-looking masses drawn out in the line of flow.

An attempt to represent the general appearance of a portion of this slice has been made at fig. 1, plate II; whilst at fig. 2, plate I (*a*), an illustration is given of the crumpling of the silvery mica as seen in this slice.

In some cases the twinning planes of the plagioclase are bent out of the perpendicular. I have occasionally seen instances of this in lavas, though it is of rather rare occurrence; and it seems to indicate conditions of strain subsequent to the crystallization of the felspar before the mineral had become perfectly rigid on cooling.

Zirkel, at p. 28 of his work already quoted, mentions the presence of fluid cavities in the quartz enclosed in garnets; but the garnets themselves, in this slice, contain numerous fluid cavities with movable bubbles. The quartz of the granite itself contains fluid cavities about the same size as those in the garnets.

No. 17.—Argillaceous schist in actual contact with a thick vein of granitic rock within 3 or 4 yards of the main mass of the gneissose granite. Same locality as the last. It is an indurated rock with minute flecks of mica visible here and there.

M.—In transmitted light the ground mass appears to be homogeneous and colourless, but thin and minute flakes of a green mica are thickly disseminated through it. Patches of opaque ferriferous material are dappled about over the field; whilst the slice is here and there stained with ferruginous material, and dots of yellow and red ferrite are occasionally to be seen. Flakes of colourless mica are sparsely scattered about, and there are numerous small fragments of a bluish-brown tourmaline. Between crossed nicols the slice presents a dark base relieved by numerous patches of semi-luminous material presenting highly irregular outlines, and bright flecks of mica.

The slice contains some air bubbles, but no liquid cavities. Some of the schorl shows that this mineral has been subjected to heat, and that the air or liquid enclosures which they contained expanded and forced a way to the surface of the mineral before its complete consolidation. An illustration of this, taken from this slice, is given at fig. 7, plate II.

No. 18.—Argillaceous schist in actual contact with the main body of the gneissose granite. From the same locality.

M.—This slice closely resembles the last. There is comparatively little schorl, and it is in very minute prisms. The slice contains numerous dots of magnetite.

No. 19.—An argillaceous schist in contact with a granitic vein, 3 or 4 yards wide, close to the main body of the gneissose granite. From the same locality. This is a more distinctly foliated rock than the preceding two specimens.

M.—The ground-mass consists of quartz in minute grains. Inter-laminated ith this are strings of a fibrous dark-green mica and strings of the crypto-ystalline mica which I have shown to be a characteristic of the gneissose anite. Muscovite is also very abundant in the slice, whilst crystals of schorl, any of them being very minute, are present in great numbers. It is of the pe and colour of that found in the gneissose granite, and for the most part it s in a zone corresponding to the plane of foliation, the crystals lying more or ss at right angles to that plane. The schorl contains numerous enclosures and me empty cavities, the contents of which have apparently forced their way rough the mineral to the surface in the manner already described. The slice ntains grains of magnetite, opacite, and ferrite, and some minute crystals of rnet; also one crystal of triclinic felspar. There are no liquid cavities.

No. 20.—Slate from the quarry near the gneissose granite on the Mamul oad, Dalhousie

M.—Under the microscope this is seen to be distinctly foliated; quartz, in inute granules, alternating with a fibrous green mica that is but feebly dichroic. ome very minute and imperfectly formed prisms of tourmaline are scattered hrough the slice.

Light flocculent clouds of nebulous matter, opaque in transmitted, and ellowish-white in reflected light, are also abundant. A sketch of a portion of his slice is given at fig. 3, plate I.

No. 21.—A spotted schist within a few yards of the gneissose granite, 'otrain Hill, Dalhousie. Viewed macroscopically this has a distinctly foliated spect, and specks of muscovite are visible here and there.

M.—The ground mass consists of quartz in small granules of very varied and rregular shapes, interspersed with crypto-crystalline mica that meanders about in ll directions.

In this ground-mass are embedded numerous crystals of muscovite, and of a lark well-laminated mica, brown in transmitted light. Some of the latter contain rains of quartz and of magnetite. Magnetite and rounded grains of opacite re rather abundant in this slice, which also contains numerous prisms and ragmentary pieces of schorl, of the same type as that in the gneissose ranite. There are also numerous micro-crystals of garnet. There are no liquid avities.

At fig. 3, plate II, I have given a representation of a portion of this slice, howing the way in which the crypto-crystalline mica and the hyaline quartz are ntermixed. The dark portions, in the illustration are intended to represent he former, and the uncoloured portions the quartz.

No. 22.—A similar rock a little further away from the gneissose granite, on he same road. It is of more spotted appearance and granular texture than the ast, having lost, in the hand specimen, all traces of foliation.

M.—This slice closely resembles the last and requires no separate descrip-ion. The crypto-crystalline mica is very abundant. Some of the grains of nagnetite are of good size.

No. 23.—A fine-grained silicious schist in contact with the gneissose granite n the cart-road, between the Mall and the Bull's Head Hotel, Sananotala.

M.—This is a distinctly foliated rock, and the description given of slice No. 19 exactly applies to this one. No liquid cavities are present.

No. 24.—A crystalline granular rock a few yards below No. 23, on the same road.

M.—This exactly resembles No. 22, and is evidently the same rock. The quartz contains no liquid cavities. Small rounded fragments of the crypto-crystalline mica are included in the quartz; whilst grains of quartz are included in all the other minerals.

In many cases small colourless microliths are attached to rounded grains of opacite in a way to suggest, at first sight, that the opacite had on cooling given off a gas that had intruded into the adjoining matrix. Illustrations of these combinations are given at fig. 6, plate II (see upper and left-hand figures). A careful study of these groups, however, showed that they are simply due to the accidental conjunction of two different minerals. Such forms as that depicted on the right hand of this figure seem to show this conclusively. The occurrence of these conjunctions, however, is so common that it seems to indicate that the rock was reduced to a sufficiently viscid and plastic condition, to allow of microliths moving by molecular attraction some little distance, at any rate, towards each other. The whole appearance of the slice, and the small rounded dots of crypto-crystalline mica included in the quartz, all point in the same direction, and indicate a viscid condition. The slice, I may add, contains numerous small rounded cavities that are probably due to shrinkage on cooling.

No. 23.—Another fine-grained silicious schist a few yards further down on the same road.

M.—This presents much the same features as the last slice. The schorl is not so abundant, and for the most part is in small prisms. The dark mica is arranged more in strings, and the crypto-crystalline mica is relatively more abundant than the quartz. In this slice it is micro-crystalline rather than crypto-crystalline.

Nos. 26 & 27.—Other speckled varieties of the crystalline granular rock a few yards further down on the same road. They contain ma grains of iron-pyrites. Sp. G. 2, 74.

M.—The description given of Nos. 22 and 24 applies equally to these specimens. Schorl is abundant.

The peculiarity of these slices is that they contain a considerable amount of zircon, in irregularly shaped granules, intimately intermixed with grains of quartz. Much of the zircon is distinctly dichroic, changing from a white, or faint bluish-white, to a delicate tint of light red. It does not exhibit colours in polarised light owing to its strong double refraction.

This is the first time that I have met with zircon *in situ* in Himalayan rocks, but a sample of the gold-bearing sands of the Sutlej river, sent me by a friend, is full of well-formed crystals of this mineral.

The quartz contains what appear to be stone cavities with fixed bubbles, whilst others have either caught up and enclosed opacite when in a plastic condition or have deposited it on cooling.

Rocks between the gneissose granite and the first outcrop of gneiss.

The cart-road, from near its junction with the Mall, between Thera and Potrain, to near the Bull's Head Hotel, Sanánotála, runs a little below the junction of the gneissose granite and the schistose rocks. Near the Bull's Head Hotel, on the neck of the Sanánotála spur, the gneissose granite re-appears, having been brought down, apparently, by the flexion of the strata. The schistose rocks between the gneissose granite on the Mall and the outcrop on the cart-road, near the Bull's Head Hotel, have been described in the preceding pages. The rocks, now to be described, are a descending series which crop out on the cart-road between the gneissose granite, near the Bull's Head Hotel, and the mica schists at Banikhet.

No. 28.—A silicious schistose rock in contact with a vein of granitic rock cutting through the schists. Viewed macroscopically two sets of lines may be made out with a pocket lens on the cut and wetted face of the hand specimen, and in the thin slice; the lines cutting each other at an angle of about 40°.

M.—Viewed under the microscope one set of lines is seen to be due to partial foliation; that is to say, to be due to the development of a tendency on the part of the dark mica to segregate in more or less parallel lines. It is noticeable, however, that the laminæ of the mica are arranged parallel to the *second set of lines*, and not to the lines of dark mica. The mica has segregated into lines, but each flake of mica in the line is arranged with its longest axis at an angle of about 40° to its own line.

The second set of lines alluded to are due to the occurrence of lenticular masses of crypto-crystalline mica, the lines of which, though discontinuous, preserve a pretty constant course in one direction. Another point noticed is that these lines of crypto-crystalline mica contain rather numerous microliths of tourmaline, the prisms of which point, as the microliths in rhyolite and similar rocks, in the direction of the flow.

These facts appear to me to indicate that the rock was subjected to two different processes of contact metamorphism; one process—due to heat—resulting in foliation; whilst the second process was probably the injection of matter from the granitic rock, possibly in a gaseous or liquid condition, along lines that followed the original direction of lamination or of cleavage.

This observation, which was very unexpected, seems to have an important bearing on the point at issue. If the crypto-crystalline mica in the schistose rocks adjoining the gneissose granite is not a product of the original constituents of those rocks but has been derived from the granite, the existence of the crypto-crystalline mica in the gneissose granite affords no evidence of the metamorphic origin of the latter or of its affinity with the schists.

The general appearance of this slice is closely similar to those of the slates in contact with the gneissose granite already described. The ground-mass consists of granular quartz. A dark green fibrous mica is very abundant, but muscovite is comparatively sparse. Schorl, as usual, is present. There are no liquid cavities. Ferrite is abundant.

No. 29.—A silicious schist adjoining the gneissose granite.

M.—This is only a variety of the spotted schists already described, as for instance Nos. 21 and 22. The crypto-crystalline mica is rather abundant and swells out into large lake-like expansions. I have observed a few stone cavities in this slice, one with a fixed bubble, and two with deposits in them.

Nos. 30, 31, and 32.—Very fine-grained schists, in descending order.

M.—These may be described together. Under the microscope they approximately resemble the slaty rock, No. 17. The ground mass consists of micro-granular quartz, in which a yellowish-green scaly mica is so abundantly disseminated as to nearly pervade the whole mass. In No. 31 it has segregated into spotty masses in which it varies in colour, in transmitted light, from a green to a rich greenish-orange colour. Some of the mica is fibrous, and is, I think, paragonite. The slices contain grains of magnetite and ferrite, and slice No. 31 contains, apparently, a little hæmatite. All contain the opaque whitish mineral described under No. 20 and micro-prisms of tourmaline. The magnetite is most abundant.

Nos. 33 and 34.—Earthy looking schistose rocks. No. 34 has a strong earthy smell, even without breathing on it.

M.—These exactly resemble 30—32 and need no separate description. No. 33 contains two minute garnets. In 34 magnetite in micro-grains is abundant. In both micro-prisms of tourmaline are plentiful.

Section below No. 4 Barrack, Ballun.

No. 35.—A fine-grained schistose rock approaching the slaty type. With a pocket lens it is seen to have a fine micaceous glaze on the splitting surface.

M.—Under the microscope the rock is seen to be made up of a mesh-work of fine fibres, or microliths, of mica, in a quartz base. Larger crystals of mica are dotted about in it here and there, and stringy agglomerations of the fibrous mica. The mica is decidedly dichroic, and each of the microliths polarises rather brilliantly. I think the species is probably paragonite.

The slice contains grains of ferrite, and I think very minute grains of magnetite; also the flocculent opaque matter previously described. In this slice its colour varies from yellowish to reddish. It is, I think, a product of the alteration of magnetite.

No. 36.—A very fine-grained, pale bluish-grey, micaceous schist. The micaceous element is much more prominent in this hand specimen than in the last.

M.—This rock is so similar to the last that a further description is unnecessary.

No. 37.—A very fine-grained silicious rock approaching the slate type.

M.—This rock is of the same type as the last two, and consists of a fibrous mica, probably paragonite, disseminated through a quartz base. It contains a long irregular-shaped, lake-like space filled with hyaline quartz that has evidently been formed *in situ*, the prisms of mica projecting into it along its outer edges. It contains some gas enclosures and a few, very few, liquid enclosures with bubbles.

No. 38.—A buff coloured, very fine-grained, friable schistose rock.

M.—The structure and material are seen to be the same as the last. The

mica is of yellowish-green in transmitted light, and it evinces a tendency to segregation, forming spots of darker colour than the ground-mass. There are some good-sized bits of ferrite.

No. 39.—A pale greenish-grey argillaceous schist.

M.—In both 37 and 39 the lines of original lamination can be distinctly traced on the cut surface with a pocket lens. In this rock (No. 39) they have suffered some contortion. The lines of incipient foliation are at a high angle to the lines of lamination in all three specimens. The microscope shows that No. 39 is composed of the same constituents as the last few described. The slice contains some micro-prisms of tourmaline.

No. 40.—A very fine-grained micaceous schistose rock.

M.—This consists of a quartz base in which a yellowish-green scaly mica is profusely disseminated. It is doubtless of the same species as the preceding. The slice is dotted over with countless cubes and octahedrons of magnetite.

No. 41.—Blue micaceous slate above Surkhi-galli.

M.—This consists of an intimate admixture of quartz in micro-grains and a green mica in minute scales. An immense profusion of magnetite grains are dotted over the field, mostly in elongated irregular forms, the longer axes of which are turned in the same direction. There are numerous micro-prisms of tourmaline and very minute crystals of sphene, which require high powers to detect. In many cases the sphene and magnetite have adhered together.

No. 42.—A pale blue slate similar to the last.

M.—This is apparently a very similar rock to No. 41; but the micaceous element is more fibrous and colourless.

No. 43.—A pale french-grey coloured argillaceous schist from the same locality.

M.—An exactly similar rock to No. 41 except that the magnetite is absent and a little ferrite has taken its place. The micro-prisms of tourmaline and sphene are abundant. I observed a liquid cavity in the mica.

No. 44.—A fine-grained friable whitish mica schist.

M.—This consists principally of minute scales of a yellowish-green mica and some minutely granular quartz. There are numerous air bubbles. I have not detected any tourmaline. Minute crystals of sphene are abundant. Magnetite and ferrite are also present.

No. 45.—A white wafery schist with a silky gloss on the cleavage surfaces.

M.—A very similar rock to the last, only the scaly mica is very colourless. The grains of magnetite and ferrite are very sparse. Micro-crystals of tourmaline and sphene as in the last. There are a few minute garnets.

No. 46. A light-grey, fine-grained silicious schist.

M.—The appearance of this rock under the microscope is very different from those described from No. 30 downwards. Its affinities are with the spotted schists Nos. 19 and 23, the latter of which it much resembles. It may be described as a micro-gneiss, and it consists of lenticular grains (eyes) of quartz and triclinic felspar set in crypto-crystalline mica which flows in ropy masses round them. The quartz very largely predominates over the felspar; indeed, the latter is sparse. Large flakes of muscovite are present, but no biotite. There are some good-sized pieces of schorl of the type present in the granitic rocks-

also a few rounded grains of what appears to be sphene. I have not been able to detect any liquid cavities even with the use of very high powers.

No. 47.—Paragonite slate (?)—An extremely fine-grained, french-grey coloured mica schist of slaty appearance.

M.—This has, unfortunately, been sliced so thickly that little can be made out, but it does not appear to differ in any essential particular from No. 41. Pounded fragments examined under the microscope confirm this impression and show that the rock is principally composed of an almost colourless mica in scales and fibres, and countless elongated granules of magnetite. The mica appears to be paragonite. There are as usual microscopic prisms of tourmaline.

No. 48.—The pearly mica schist of Banikhet.

M.—This is closely similar to No. 44. It is principally composed of a scaly mica, varying in colour from white to pale green, with ferruginous yellow stains in spots here and there. There is an admixture of quartz in a finely granular condition. The beautiful pearly opalescence of the thin slice, seen in reflected light without the aid of a lens, appears to be due to the presence of myriads of air or gas bubbles with which this rock is crowded. There are countless elongated grains of magnetite; the usual micro-prisms of tourmaline are also present; also micro-crystals of sphene.

Conclusion.

The general conclusions at which I have arrived from the detailed study of the Dalhousie rocks are as follows:—Fifteen specimens of the gneissose granite from various parts of the Dalhousie ridge, exhibiting some typical varieties of structure when examined macroscopically, are seen, when examined with the aid of the microscope, to be mere varieties of the same rock. No essential difference of any kind can be detected between them. All of them contain orthoclase microcline, plagioclase, quartz, muscovite, magnetite, garnets, and liquid cavities containing movable bubbles. Six of the specimens contain schorl in some abundance, and all but three of the thin slices contain biotite. In all the quartz exhibits a polysynthetic structure very prominently, whilst all contain crypto-crystalline mica.

Some of the slices give unmistakable indications of having been reduced by hydro-thermal agencies to a plastic condition, and exhibit true fluxion structure. It is also important to note that the specimens which exhibit these characteristics most prominently are those which show, when viewed macroscopically, a pseudo-foliation, and have consequently a gneissose aspect.

The rocks are not true granites, but it does not follow from this fact that they are necessarily of metamorphic origin. Between the deep-seated roots of volcanos and the lavas that have actually flowed out at the surface of the earth's crust, there must of course be many gradations. The presence of the crypto-crystalline mica in the Dalhousie gneissose granite, that is to say, the presence of an imperfectly crystallised residuum, seems to indicate their affinity with the felspar porphyries. Indeed specimen No. 13 approximates in its macroscopical appearance very closely to a felspar porphyry.

Allport, in his paper "On the Metamorphic Rocks surrounding the Lands'-end

Mass of Granite," Q. J. G. S., XXXII, 407, shows that the mineralogical changes produced in clay slates by the intrusion of a mass of granite are chiefly the development in them of some of the minerals which constitute its own mass; that is to say, quartz, tourmaline, and three kinds of mica; occasionally tremolite, magnetite ("and andalusile ?"), and in some localities felspar. The structural changes produced in clay slates by contact metamorphism, according to Allport, are " (*a*), foliation more or less perfect, with every gradation from nearly straight parallel lines to the most complicated contortions; and (*b*), concretionary, showing a decided tendency to segregation of both quartz and mica, the result being a spotted schist."

A precisely similar influence appears to have been exercised by the gneissose granite on the slates in contact with it at Dalhousie. As to structure, we have seen that foliation has been produced and "spotted schists" have been formed; whilst schorl, garnet, dark mica, muscovite, and magnetite have been introduced or created out of the constituents of the slate.

As regards mineralogical changes, Allport noticed in the rocks described by him in the paper just quoted, that the strata near the granite were "far more highly silicated than those at a distance from it," and he expressed the opinion that "there can be no doubt that much of the quartz has been derived directly from the intruded rock."

In the case of the rocks under consideration, a study of slice No. 28 led me to the conclusion that the crypto-crystalline mica seen in the schists in contact with the granitoid rock, is due to the injection of matter from the granitic rock into the schists in a gaseous or liquid condition.

Two other points are to be noted: *first*, that though the gneissose granite is rich in felspar, only one small crystal of this mineral was found in the numerous slices of rocks in contact with the gneissose granite examined under the microscope; *secondly*, that though liquid cavities are most abundant in the quartz of the gneissose granite, they are entirely absent from the schists immediately in contact with it, and are almost entirely absent from the schistose rocks below them.

Professor A. Geikie, in a critique on a paper by Père Renard, of the Royal Museum, Brussels, on the crystalline schists of the French and Belgian Ardennes (Nature, December 7, 1882) which came to hand after I had finished my examination of the slices now described, comments on the absence of fluid cavities in the quartz of the Ardennes schists as follows:—"In subjecting to microscopic examination thin slices of some of these altered rocks, M. Renard noticed that the quartz granules, presumably of clastic origin, have lost the liquid inclusions so generally found in the quartz granules of old sedimentary strata. This fact (already observed by Sorby in the case of sandstone invaded by dolerite) seems to indicate that the sand-grains have not escaped the influence of the changes which have so profoundly affected the other constituents of the former sediment."

Dr. Sorby notices this effect of contact metamorphism in his Anniversary Address (Q. J. G. S., XXXVI, 1882):— "One point of interest is," he writes, "that although the grains of sand contain many cavities which no doubt, as usual, originally contained water, they have all lost it, as though it had been expelled

by the heat of the igneous rock, in the same manner as it is easily expelled from unaltered quartz by a high artificial temperature."

That the absence of liquid cavities, in the schistose rocks in contact with the gneissose granite, is due to heat, is rendered highly probable by the fact noted in the foregoing papers (see notes on slices 17 and 19) that pieces of schorl retain internal evidence that the contents of enclosures in this mineral had expanded by heat and forced their way to the surface.

We have already seen that whilst the granitic rocks abound in felspar, the altered slates in contact with them have not developed that mineral. I have also given my reasons for believing that the gneissose granite was reduced by *hydro-thermal* action (evidenced by the great abundance of its liquid cavities) to a plastic condition; and that portions which present a decided gneissose aspect exhibit true fluxion structure.

We have also seen that the schists in contact with the gneissose granite exhibit the peculiarities usually developed in rocks by contact metamorphism; that is to say, minerals present in the granitic rock, schorl, biotite, muscovite, garnet, magnetite, and crypto-crystalline mica have been developed in them near their point of contact; whilst the water, which was presumably present in the quartz of the clastic rock, has been driven off by heat. These facts, it seems to me, render it improbable that the features presented by the Dalhousie rocks are the result of selective metamorphism applied to a conformable series of sedimentary rocks.

The slaty and schistose rocks between the gneissose granite and the outer band of gneiss, though very varied in macroscopic aspect, present little variation under the microscope. They consist of an admixture of quartz and mica. The quartz contains no liquid cavities. One exception to this only was noted in the case of clear quartz plugging what may have been a pre-existing cavity, and which was probably filled with foreign material from intrusive granitic masses in its vicinity.

The quartz in all the slices described has lost all trace of its original clastic origin, and the mica has certainly been formed *in situ*. The change in the shape and appearance of the quartz grains has doubtless been due to after-growth in the manner pointed out by Dr. Sorby (Ann. Address, Q. J. G. S. XXXVI, 62).

The mica is of a different species from the micas present in the gneissose granite, and much of it appears to be paragonite. Some of the lower beds, as for instance No. 47, are, I think, entitled to the name of paragonite slates.

The general character of the schists may be said to be more silicious towards the gneissose granite and more micaceous towards the first outcrop of gneiss.

As the outer band of gneiss is neared, sphene makes its appearance in micro wedges and crystals, and is rather abundant. Garnets are rare. On the other hand, zircon is present in the spotted schists next the gneissose granite, and garnets are not uncommon.

Very minute prisms of tourmaline, of bluish colour in transmitted light, are present more or less throughout the schistose beds; but schorl, of the type found in the gneissose granite, is confined to the rocks in immediate contact with it.

Schorl also re-appears in No. 46, but the whole aspect of that rock is suggestive of the near proximity and the contact action of granitic rocks.

The metamorphism of the slate series, as a whole, does not seem to require the aid of great heat to explain it, for the action of moderately heated water is sufficient to account for the formation of the hydro-micas, the minute prisms of tourmaline, and the addition of quartz to the pre-existing grains of that mineral. The gneissose granite on the other hand has undoubtedly been fused, whilst its action on the slaty series in immediate junction with it has been analogous to the contact action of eruptive granite.

In conclusion, whilst I am not able to affirm as the result of my investigations up to date, that any of the axial gneiss of the Dhuladhár range is true gneiss, I find that it presents the characteristics of an igneous rock. It has been in a fused condition; it shows fluxion structure; it invades the rocks immediately in contact with it; its structure and composition is uniform over wide areas; and it expands suddenly along the line of strike from a width of 250 feet to a width of 6½ miles. The facts, at present known, point to the conclusion that the gneissose granite is an intrusive rock and has been squeezed up through a faulted flexure along an axis of maximum strain.

In my paper on the Geology of Dalhousie (*Supra*, Vol. XV, p. 44) I wrote—'The granitoid gneiss is highly porphyritic, and is undistinguishable from, and doubtless is identical with, the 'central gneiss.'" As a result of the subsequent microscopical study of the Dalhousie rocks, I have dropped the term "granitoid gneiss" in my present paper, and have substituted gneissose granite for it; and it is for consideration whether the term "central gneiss," introduced by the lamented Dr. Stoliczka, and since used to denote the "granitoid gneiss" of the North-West Himalayas, should not be discontinued in future.

The terms "central gneiss" and "granitoid gneiss" insensibly suggest cambrian and pre-cambrian times; and their use is apt to create a prejudice in the mind of the student both as to the origin and the age of the rock, for the tendency of petrological inquiry in the present day is to predicate a great geological age for crystalline rocks in which the granitic structure is due to regional metamorphism. But if the conclusions at which I have arrived in this paper are sound, it follows that the gneissose granite of the Dhula Dhár is of eruptive origin, and instead of being an archæan, cambrian, or "converted" silurian rock, it is in reality of tertiary age, and was brought into its present position in the course of the throes that gave birth to the Himalayas.

I do not intend to draw the inference that all the granitoid, and still less that all the gneissose rocks of the North-West Himalayas are of eruptive origin,—that would be too sweeping a generalisation to make from the facts at present ascertained,—but I think the most natural conclusion to draw from the evidence before us, taken as a whole, is that the "central gneiss" and "granitoid gneiss" of Dalhousie is really an eruptive rock; that is to say, whether it has travelled a short distance, only, from its seat of extreme metamorphism, or whether it was more or less directly connected with volcanic or plutonic action, it was in actual motion in a fused or plastic condition and occupies now the position of an intruder

in the silurian series. I think the balance of evidence is against the supposition that it was reduced into a fused condition *in situ*.

DESCRIPTION OF PLATES.

PLATE I.

Fig. 1. Gneissose granite, Dalhousie. This sketch, taken from slice No. 1, is intended to show the polysynthetic structure of portions of the quartz.

" 2. A portion of slice No. 16, taken from a granite vein intruded into slate, Dalhousie; (*a*) shows the crumpling of mica due to traction. See also fig. 1, plate II.

" 3. A portion of slice No. 20. Slate from the quarry near the gneissose granite, Dalhousie.

PLATE II.

Fig. 1. A portion of slice No. 16, taken from a granite vein intruded into slate. See also fig. 2, plate I.

" 2. A portion of slice No. 15; gneissose granite in contact with slate, above the slate quarries, Dalhousie. This sketch represents the mode in which the crypto-crystalline mica and biotite are drawn out into strings.

" 3. A portion of slice No. 21; spotted schist within a few yards of the gneissose granite; Dalhousie. The sketch shows the way the crypto-crystalline mica and hyaline quartz are intermixed.

" 4. Sketch of a biotite crumpled up by traction, taken from slice No. 15— gneissose granite in actual contact with slate.

" 5. Showing a common mode of occurrence of mica in connection with the ropy strings of crypto-crystalline mica.

" 6. Showing the mode in which grains of opacite and microliths of an undetermined mineral adhere together.

" 7. A crystal of schorl taken from slice 17, showing that air or liquid enclosures originally contained in it had subsequently expanded from heat and forced their way to the surface of the mineral before its final consolidation.

Fig 1 × 60

Fig 2 × 60

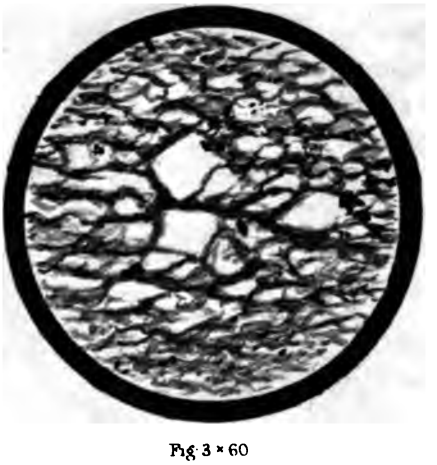


Fig 3 × 60

Reproduced in heliogravure from the original drawings at the Surveyor General's Office, Calcutta.
May, 1883.

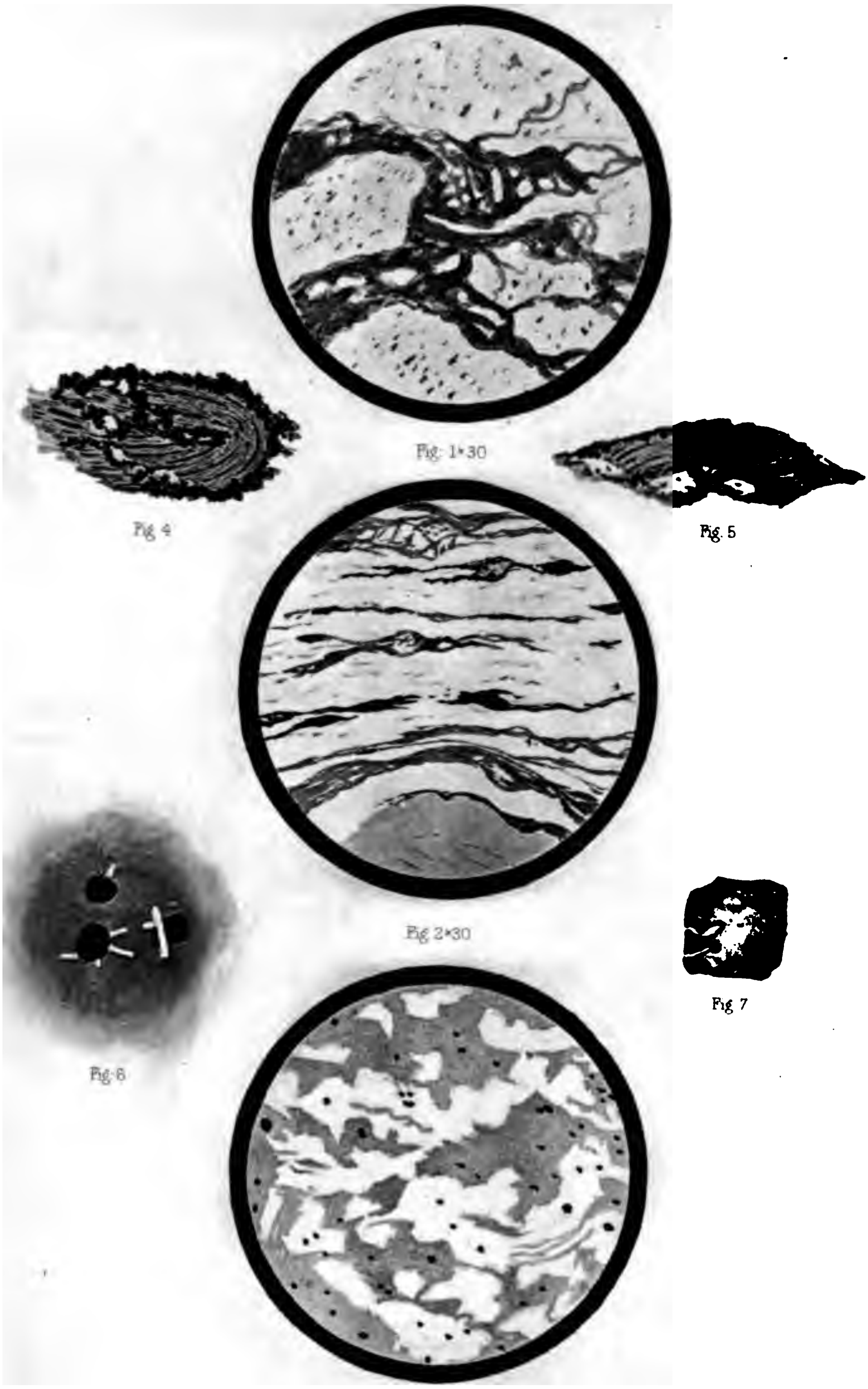


Fig: 1×30

Fig 4

Fig. 5

Fig 2×30

Fig 6

Fig 7

Fig: 3×100

Reproduced in heliogravure from the original drawings at the Surveyor General's Office, Calcutta.
May, 1883.

On the lavas *of* Aden—*By* COLONEL C. A. McMAHON, F.G.S.—(*With a plate.*)

A BRIEF account of the extinct volcano of Aden is given by Mr. F. R. Mallet, F.G.S., in his paper "On the Geological structure of the country near Aden, with reference to the practicability of sinking Artesian Wells." Vol. VII, Memoirs, Geological Survey of India.

The following description of the lavas found at Aden is taken from Mr. Mallet's paper: "The varieties of rock met with are very numerous; there are perfectly compact lavas of brown, grey, and dark-green tints, sometimes containing crystals of augite and not unfrequently those of sanidine, and there are rocks exhibiting every degree of vesicularity until we arrive at lavas resembling a coarse sponge and passing into scoriæ. The vesicles again are in some specimens globular, and in others flat and drawn out. In some places the lava is quite schistose, and might if seen *per se* be easily mistaken for a metamorphic rock. Such lava is sometimes vesicular, but by no means always so, at least not to the naked eye. Volcanic breccias are also met with, as near the main pass where fragments of dark-green lava are imbedded in a reddish matrix. Tufas are also present, but apparently to a limited extent. Some specimens of tufa shown me by Captain Mander, the Executive Engineer, were made up principally of fragments of pumice, from which it would appear that pumice must be amongst the volcanic products, though I am not aware of any locality in which it is found *in situ*. Obsidian is to be met with occasionally in thin seams."

I have not met with any detailed account of the micro-petrology of the Aden lavas, but the following passing allusions to them may be quoted here. Mr. Frank Rutley, F.G.S., in his Study of Rocks, p. 152, 2nd edition, writes as follows: "A globular condition of silica has been lately described by Michael Lévy as occurring in the euritic porphyries of Les Settons, and similar globular conditions of silica have been observed and noticed by M. Vélain in a quartz trachyte from Aden. The former author regards this condition as intermediate between the crystallized and the colloid forms of silica."

Professor A. Daubrée, in his paper on zeolitic and silicious incrustations (Q. J. G. S., XXXIV, 73), states that silicious infiltrations are found in many volcanic rocks of the "trachydoleritic class," and refers to Aden as one of his examples.

The above are the only references to the Aden rocks that I have yet met with, and the following account of some of the lavas to be found at that place may not be without interest. As I have never been able to remain at Aden for more than a few hours, my examination of the extinct crater has only been a cursory one. The specimens from the vicinity of the tanks were collected by me, but the others were collected for me by a resident Engineer through the kindness of a friend. I proceed to describe the specimens in detail.

Basalts.

No. 1.—A grey compact lava. With the aid of a pocket lens, crystals of felspar and numerous dots of a greenish-yellow amorphous mineral are visible here and

there. The locality in Aden from which this specimen was obtained is unknown. Sp. G. 2·78. The rock is magnetic and under the blowpipe fuses to a black bead.

M.—The base consists of a devitrified glass in which dendritic and rod-like forms of magnetite are abundant. Magnetite is also present in regular crystallographic forms.

In this base countless prisms of felspar are starred about; whilst large porphyritic crystals of that mineral are visible here and there. The porphyritic crystals are all plagioclase with the exception of one medium-sized prism which is orthoclase. Many of the minute prisms are visibly triclinic and the others are presumably so. The porphyritic felspars contain numerous enclosures of the base.

There are several augite crystals in the slice, but they are not very fresh. Part of the magnetite has been converted into hæmatite or göthite, imparting a reddish tinge to the slice, when viewed in reflected light.

The greenish-yellow amorphous mineral, alluded to above, is probably a secondary product of the decomposition of olivine, but none of the unaltered mineral is to be detected.

This rock is evidently an ordinary basalt.

No. 2.—A very dark-grey lava from Station Flagstaff Hill. It is highly vesicular, the area of the vesicles in the thin slice being nearly equal to the substance of the lava itself, but they are too minute to be seen by the unaided eye.

The rock is decidedly magnetic and fuses readily to a black bead. It seems to be a favourite rock for building purposes, and it is said to take the chisel well.

M.—The ground-mass is perfectly opaque except at the edges of the vesicular spaces and at the ends of felspar crystals, where it is seen to be made up of microscopic globulites and grains of crystalline matter. Some of this globulitic granular matter appears to be augite.

The ground-mass contains numerous crystallites and small crystals of felspar, several of which are distinctly triclinic. They contain many enclosures of the base, and some are mere skeleton crystals. Some of the larger felspars enclose prisms of apatite.

Several augites are visible in the ground-mass.

This specimen is also, I think, a basalt.

No. 3.—A very dark-grey finely vesicular lava closely resembling the last. The rock is magnetic and it fuses under the blowpipe to a black bead. From Ras Baraldu.

M.—This so closely resembles the last that a separate description is not necessary. The vesicles are not so uniformly distributed as in the last specimen and merge into elongated confluent cavities. The thin slice in reflected light has a warm brown tint. The ground-mass is not so absolutely opaque as the last specimen. In the larger felspars the enclosures of the base are so abundant as to give them quite a skeleton appearance. A fragment of augite is present in the ground-mass.

This is said to be a good building-stone and to take the chisel well.

No. 4.—A dull red highly vesicular lava. It powerfully affects the magnet,

and it fuses under the blowpipe to a very dark mass that adheres to the magnet. Locality from which obtained unknown.

M.—The ground-mass is quite opaque.

Andesites.

No. 5.—A slaggy-looking lava with crystals of felspar visible here and there. Some vesicular cavities contain a zeolite which also forms incrustations on the surface. The specimen was obtained near the Station Point Cemetery. Sp. G. 2·64. The determination of the specific gravity may be a little under the mark, as there are a few vesicular cavities. The specimen is powerfully magnetic, and it fuses at the edges.

M.—The ground-mass is nearly opaque and consists of multitudes of grains of magnetite disseminated through a base of flocculent matter, probably a product of devitrification rather than of decomposition. None of the magnetite exhibits regular crystallographic forms, and part of it has been converted into hæmatite or göthite. The latter imparts a reddish and pseudo-felspathic appearance to much of the base when viewed macroscopically.

The ground-mass contains numerous micro-prisms of felspar, whilst felspars of large size are porphyritically embedded in it. The latter are nearly all visibly triclinic, and contain very numerous enclosures of the base, and buff coloured amorphous masses, that probably represent decomposed augites. Augites are not unfrequently caught up in large felspar crystals, as is the case, also, in slice No. 1. The felspar contains gas cavities and enclosures of ferrite.

No. 6.—A dark-grey vesicular lava from the vicinity of Station Point Cemetery. The hand specimen resembles the mudstone matrix of a conglomerate from which the pebbles have been extracted, the vesicular spaces having very smooth and regular surfaces as if they had enclosed hard substances. Sp. G. 2·61. The hand specimen is strongly magnetic and fuses easily under the blowpipe to a black bead which adheres to the magnet.

M.—A striking feature in this slice is the presence of numerous crystals of a red mineral which I have not been able to satisfactorily identify. It occurs in six and four-sided prisms, and in irregular shapes, and in fragment-like pieces. Some are in long and thin prisms, others in rather massive lumps. In transmitted light it is of rich orange red colour—yellowish orange when thin—deeper red when thick. When the polariser alone is revolved it absorbs light distinctly, but does not change colour. It very frequently contains enclosures of felspar, and in one instance the latter has conformed to the shape of the prism. These enclosures seem to indicate that the mineral is an original constituent of the rock and not a secondary product. The cleavage is irregular. The angle of the prism varies very much; some being nearly right angles, others being very obtuse. The average of the measurements of 17 prisms come to 103° 52′. In a few, not included in this average, adjacent faces intersected at an angle of 135°. The variation in the angle seems due to the mineral itself and not to oblique slicing.

Extinction coincides with the length of the prism and with the diagonal of the prismatic angles seen in cross section.

Between crossed nicols the mineral changes from dark to its natural colour in this slice, but in No. 16 it changes from dark to a rich crimson colour.

The prevalence of four-sided prisms is against the mineral being rubellite, or an allied species of tourmaline; its orange colour and transparency shuts out the idea of its being hæmatite, whilst the extinction shows that it is not a monoclinic pyroxene. In some respects it would do for brookite and the angles would agree fairly well with the Arkansas variety of that mineral, but I do not feel satisfied that it is brookite.

Can it be an ortho-rhombic pyroxene? the presence of which mineral in augite-andesites has recently been determined by Cross, Rosenbusch, and Teal. Its colour is not favourable to this supposition. Altogether the mineral is rather a puzzle to me at present.

The base of the rock under consideration consists of a slightly devitrified glass, of pale yellowish colour, in which are disseminated a micro-crystalline mixture of felspar, magnetite, and granular hornblende or augite. It is not dichroic and from the angle of extinction in some pieces of prismatic form I think it is augite.

Besides the micro-prisms of felspar, scattered in great abundance through the base, felspars in larger prisms are porphyritically imbedded in the ground-mass. They are nearly all visibly triclinic, as are some of the very small ones.

Considering the low specific gravity of the last two specimens, I think they must be classed as andesites. They are evidently transitional forms between the basalts and the trachytes of the Aden volcano.

Trachytes.

No. 7.—A grey compact lava with minute crystals of sanidine visible here and there. From the vicinity of the tanks. Sp. G. 2·66. The hand specimen is magnetic, but not strongly so. Under the blowpipe it fuses to a dark bead.

M.—The ground-mass consists of an intimate mixture of minute felspar prisms and irregular-shaped pieces of felspar: countless patches or granules of hornblende, and grains of magnetite and ferrite. In this are porphyritically imbedded large crystals of felspar; plagioclase and sanidine being almost equally abundant. Two of the latter present penetration twins, the others are twinned on the Carlsbad type.

The sanidine contains numerous enclosures of the ground-mass, and also stone or glass enclosures that have deposited mineral matter on cooling. Two of these are depicted at figs. 7 and 8.

The margin of many, and occasionally the whole of the sanidines in this, and in most of the slices about to be described, have a curious dusty appearance. Under high powers these felspars are seen to be full of imperfectly defined contorted fibrous particles of a doubly refracting mineral, and the dusty appearance seems to be due to the irregular intergrowth of either quartz, or another species of felspar. These enclosures do not interfere with twinning, and the latter shows that the mineral is sanidine and not nepheline.

In a portion of the slice the hornblende and magnetite are arranged in dendritic combinations.

The hornblende exhibits dichroism very strongly. One set of cleavage lines are occasionally to be seen, and the angle of extinction is characteristic of hornblende.

The slice contains a piece of the red mineral described under No. 6.

No. 8.—A grey compact rock with numerous crystals of sanidine imbedded in it. From the vicinity of the tanks. Sp. G. 2·63. The hand specimen is distinctly magnetic; under the blowpipe it fuses at the edges and adheres to the magnet.

M.—This specimen is more felspathic than the last, and the base in transmitted light is clearer. It consists of a micro-crystalline admixture of felspar, in which very numerous patches of a yellowish-green hornblende, and grains of magnetite, are freely scattered about. There are also a good many patches of hæmatite, or göthite, most of which are directly connected with magnetite grains.

There are two sizes of felspar crystals porphyritically imbedded in the ground-mass, namely, medium-sized and very large sized. Nearly the whole of the felspar of all sizes is orthoclase, but there are a few prisms of plagioclase. The larger prisms contain numerous rod-like belonites, some of which are fractured, which are doubtless imperfectly formed apatite crystals. In some cases opacite, or granular magnetite, has formed on these belonites, and sketches of three of them are given at figs. 11, 12, and 13. These combinations are particularly worth noting, because exactly similar forms are common in the gneissose granite of the North-West Himalayas, and in both cases they seem to afford evidence of the rocks which contain them having been reduced to a fused or plastic condition.

In fig. 13 the magnetite is seen to have formed on the belonite after the consolidation of the latter, and to have completely embraced it. In fig. 12 the magnetite has partially encircled the larger mineral in its arms, whilst in fig. 11 it has consolidated along its edge. In fig. 11 a cavity, running with the length of the belonite, is seen depicted at (*a*). It is probably due to shrinkage on cooling.

It is interesting to find bodies, such as those described, common to acid lavas and the gneissose granite of the Himalayas.

The felspars contain thousands of air or gas cavities.

An isotropic mineral is to be seen here and there; one of the crystals presents a six-sided outline—the sides being equal—whilst the others are in more rounded forms. It is doubtless garnet.

No. 9.—A grey compact rock, somewhat mottled in appearance, with minute prisms of felspar visible here and there. The specimen was obtained near the tanks. Sp. G. 2·60. The rock attracts the magnet, and it fuses under the blowpipe to a dark bead.

M.—The ground-mass is dark owing to the abundance of magnetite; in other respects it does not differ from that of the slices of trachyte previously described. Amongst the large porphyritic crystals plagioclase preponderates over the sanidine, but the smaller crystals all belong to the latter species. Some of the triclinic felspar is in the form of long thin prisms.

The larger felspars contain numerous enclosures of the ground-mass. In some they are so abundant as to give the prisms a somewhat skeleton appearance.

[illegible]

[illegible]

The slice contains a garnet. Much of the magnetite has [illegible], or [illegible], while an apparently hydrated species of iron oxide [illegible] the matrix round the magnetite grains.

The texture of this specimen appears to be approaching the [illegible] and is on the border line between the two.

A sketch of a portion of this slice is given in fig. [illegible]; a group of felspar crystals, round which much magnetite has collected, occupies the centre of the illustration. The felspars are seen to have caught up numerous fragments of the ground-mass which are aligned in general correspondence with the cleavage planes of the containing felspars.

No. IV.—A compact light grey coloured rock with minute crystals of sanidine visible here and there. This was obtained near the [illegible]. Sp. gr. [illegible]. The hand specimen contains, caught up in the compact rock, several fragments of pumiceous lava in which vesicular cavities are numerous. This seems sufficient to account for the abnormally low specific gravity, as the air caught up in the vesicular cavities of the pumiceous fragments would be sufficient to [illegible] the result. The hand specimen is magnetic, but it is almost [illegible] under the microscope.

M.—This seems to be quite a typical trachyte. The ground-mass appears to be made up of an aggregation of felspar microliths. In this are imbedded medium and large sized felspar crystals. Amongst the two latter sanidine is abundant and in its very typical forms. The slice contains very little plagioclase, and the felspar micro-prisms of the base are either undifferentiated or are orthoclase.

Hornblende occurs in patches throughout the ground mass, though it is not so abundant as in some of the slices previously described. There are one or two fragmentary looking pieces of augite. In transmitted light it is of a greenish-brown, or brownish-green, but of so pale a tint as to be almost colourless. It is not dichroic, and in extinction and other characteristics it agrees with augite. The outer edge is a good deal corroded, but internally it is perfectly fresh. Some of the hornblende is much corroded and altered. It is of yellowish-green colour, and most of it is decidedly dichroic.

The ground-mass contains numerous grains of magnetite. Hæmatite or göthite is present here and there, and has penetrated cracks in the sanidine; it also occurs in patches in the latter. Some apatite is also present.

A long cavity in the slice is stopped with calcite, which is here and there crystallized in characteristic forms. The calcite encloses some minute prisms of epidote. A zeolite appears to be also present.

Quartz trachytes.

No. II.—A grey compact rock with minute crystals of sanidine visible here and there. Part of it is of dark grey, and part a very light grey colour; and when examined with the aid of a pocket lens, it has the appearance of two magmas imperfectly mixed together. The specimen was obtained near the tanks. Sp. G. 2·60. The rock is strongly magnetic. The dark portions fuse, under the blowpipe, to a dark magnetic bead, but the light portions fuse at the edges only to a transparent colourless glass.

M.—This is a very beautiful specimen in the field of the microscope. The ground-mass in transmitted light is, in parts, very clear and transparent, and in other parts, representing the dark portions previously alluded to, the magnetite and hornblende are crowded together, so as to almost cover an area equal to that occupied by the felspar. In the clearer portions of the ground-mass the magnetite and hornblende are in larger and in more perfectly crystallized grains. In the dark portions much of the hornblende is in an embryonic condition, being shapeless aggregations of minute granules, the optical characters of which are indistinct.

From the microscopic examination of this slice, I am disposed to think that the mottled character of the rock is due to segregation.

There are numerous large crystals of sanidine scattered through the ground-mass besides others of medium size. Plagioclase is sparse. The large felspar crystals contain numerous enclosures of hornblende and a profusion of stone enclosures. The curious dusty appearance seen along the border of sanidines, described under No. 7, is very prominent in those of this slice.

Patches of hæmatite or göthite are visible here and there, and some of it is distinctly traceable to the alteration of magnetite; whilst large grains of the latter have also stained the matrix for some distance round them with a yellowish doubly refractive substance.

The slice contains a garnet and a little apatite. Here and there patches of hornblende very much resemble leaflets of mica, but I do not think any of them are really that mineral, as they are of exactly the same tint as the undoubted hornblende contained in the slice, and no trace of cleavage is visible in any of the flakes alluded to. The slice, however, contains a thin string of crypto-crystalline mica meandering about in it, similar to that described in my paper on the gneissose granite of Dalhousie. This additional link connecting acid volcanic rocks with the gneissose granites of the North-West Himalayas is most interesting.

Free quartz is to be seen here and there in the ground-mass. It is evidently a residuum, and, like the quartz of granite, it is moulded on to the other minerals.

The slice also contains another specimen of the red mineral described under No. 6.

No. 12.—A pale grey compact rock with crystals of sanidine porphyritic in it, from the vicinity of the tanks. Sp. G. 2·57. The hand specimen is magnetic. Under the blowpipe portions fuse to a magnetic bead, whilst other portions are but slightly acted on.

M.—This specimen so closely resembles the last described that only a few additional remarks are needed. Plagioclase is subordinate to the orthoclase. Magnetite is plentiful and is in well-shaped grains. Hæmatite is also abundant and for the most part assumes dendritic forms, and is but feebly translucent.

Hornblende is very abundant, being present in both the ground-mass and in the felspar crystals; and some of the crystals present well-shaped six-sided prismatic sections.

Apatite is extremely abundant in the ground-mass, and the rock, when examined chemically, gives the phosphoric acid re-action with molybdate of ammonia very decidedly.

The slice contains two shapeless garnets.

Glass and stone cavities are very abundant in the felspar crystals, and are, for the most part, of types similar to figs. 4 and 5. Figs. 9, 10, and 16 are taken from this slice.

As in the last specimen, free quartz is present in the ground mass.

No. 13.—A mottled grey compact lava with felspar facets visible here and there. It was obtained near the tanks. Sp. G. 2·56. It is magnetic, and its behaviour under the blowpipe is as in Nos. 11 and 12.

M.—This specimen is so similar to the last that a detailed description is unnecessary. The ground-mass is not as clear as the two last slices; but the felspar crystals, on the other hand, do not contain hornblende, and they are much more free from enclosures generally.

Apatite is very sparse, and there are no garnets. Hæmatite is not so abundant, and it is not in dendritic forms.

The slice contains an augite with a deep dark border.

Numerous glass or stone enclosures are to be observed in the sanidine, illustrations of which are given at figs. 4 and 5. In some the matter deposited on cooling appears to be partly mineral and partly gaseous, as in figs. 6, 9, and 16; that is to say, a gas appears to have first separated from the glass, on the consolidation of the latter, and then on cooling to have deposited mineral matter previously held in suspension.

Numerous gas or air bubbles are present in the ground-mass.

Free quartz is present as in the last two specimens.

Fluxion structure is observable in a portion of the ground-mass, where the microliths of felspar are seen to flow round a large crystal.

A sketch of a portion of this slice is given at fig 1. It is not possible on the scale at which it is drawn to attempt to depict the microliths of the ground-mass.

No. 14.—A light grey compact rock with sharply defined patches of a dark lava visible here and there imparting a brecciated appearance to the hand specimen. This lava occurs near the tanks. Sp. G. 2·48. The rock attracts the magnet, but fragments of it are infusible before the blowpipe. Facets of felspar are visible in the dark and light portions alike.

M.—The ground-mass is clear owing to the comparative sparseness of magnetite. There are only two or three small pieces of hornblende present in the slice.

There is no plagioclase, but sanidine is very abundant, and, as usual, is present in very large, in medium, and in minute crystals.

Quartz is abundant and is a much more prominent feature in the ground-mass than in any of the specimens previously described. Over about half the total area of the slice, the quartz is intimately intermixed with the felspar of the ground-mass, and in polarised light the combination of the two present a curious sieve-like appearance, the quartz constituting the meshes. Here and there free quartz forms larger masses having an irregular ramifying external outline. Minute crystals of sanidine are frequently imbedded in the free quartz.

There are a few small garnets, whilst magnetite, ferrite, and hæmatite or göthite are present as usual.

No. 15.—A greenish-grey vesicular lava from behind the post office. The greater part of Steamer Point Church is said to be built of this rock. From a builder's point of view, it is said to weather badly. The hand specimen is feebly magnetic; and under the blowpipe it becomes glassy on the surface, but does not fuse to a bead.

M.—I have examined four slices of this interesting lava. The ground-mass is micro-aphanitic, and is composed of minute prisms of felspar radiating in all directions. Grains of quartz are visible here and there in the ground-mass, but they are most abundant along the margins of the vesicular cavities when they exhibit rounded and hexagonal outlines. It is I think, tridymite.

The quartz contains numerous liquid cavities with enclosed bubbles, a fair proportion of which are movable. The size of the bubbles, relative to that of the cavities containing them, varies so much that no reliable calculation can be based on the proportion between the two. One of the quartz grains contains glass enclosures that have deposited mineral matter on cooling, and one of them has several fixed bubbles. The ground-mass contains many air or gas bubbles.

There are no porphyritic crystals of felspar.

Hornblende is very abundant; most of it is in acicular prisms of irregular outline, and rather pale green colour, resembling the hornblende of the Wolf rock (phonolite) of Cornwall; but there are larger stumpy prisms, here and there, of bluish to dark green colour in transmitted light, that have sharp outlines, give good six-sided sections and occasionally exhibit cross prismatic cleavage lines. It is decidedly dichroic changing from brown to bluish-brown; but under crossed nicols the absorption is so powerful that the colours exhibited are very feeble.

No. 16.—A light grey vesicular lava from Flag Staff Hill. Sanidine and quartz are to be observed here and there. It is slightly magnetic and fuses at the edges. Numerous round silicious granules with rough surfaces are visible in the vesicular cavities; they are dull and somewhat opalescent-looking, and have none of the liquid lustre of vitreous quartz. Most of them are globular, but some are flattened and present hexagonal outlines and are seen to have a yellowish nucleus. They are infusible under the blowpipe, and hydrochloric acid takes no notice of them.

M.—Under the microscope these spherulitic bodies are seen not to be exclusively confined to the edges of the vesicular cavities, but to occur occasionally

in the ground-mass itself. Their central portions are, in transmitted light, of buff colour, and are feebly translucent, but the outer portions are transparent. Most of the globular bodies have rounded outlines, but others are flattened at the poles and present a hexagonal prism in section. Those which occur along the edges of vesicular cavities are segments of circles, the yellow nucleus being truncated and abutting directly on the edge of the ground-mass. Under crossed nicols the transparent portion is seen to have a distinctly radiated structure, and in some a dark cross is visible. They polarise in simple black and white and never exhibit colours. In some, the rough exterior surface, alluded to in my remarks on the macroscopic aspect of the rock, appears to result from minute prisms, or minute plates of tridymite projecting from the outer surface. In both cases the angles of adjoining faces are approximately 120°.

These globular bodies seen in section resemble the spherulites of rhyolites, dacites, and acid vitreous rocks, and were those found in the ground mass, seen by themselves they would undoubtedly be taken for ordinary spherulites; but the way they stand out from the surface of the vesicular cavities, their occasional hexagonal outline, and the fact that the yellow globular nuclei of those which line the vesicular cavities ar usually bisected by the bounding surface of the ground-mass, and are not continued into it, shows that they differ from ordinary spherulites. They have evidently been formed, in the great majority of cases, either by the exudition of silica from the base into the vesicular cavities, or have been deposited in these cavities through the agency of steam or water; and are not, like ordinary spherulites, the product of the devitrification of the glassy base.

I presume that these globules are identical with those noticed by M. Vélain (see *ante*). Their behaviour under crossed nicols is not, however, similar to M. Michael Lévy's description of the globular silica occurring in the euritic porphyries of Les Settons.

It is not quite clear what Michael Lévy means by a "condition *intermediate* between the crystallized and the colloid forms of silica." It seems to me that the globular silica of the Aden lavas is only a variety of hyalite, and that its peculiarities are principally due to an intergrowth, or rather to a successive formation of hyalite and tridymite. The nuclei are probably formed of common opal.

The ground-mass of the rock under consideration is micro-aphanitic, and consists, as in many of the previous specimens, of light clear portions and dark portions, as though two magmas had imperfectly mixed together.

Some large porphyritic crystals of felspar are triclinic. Some of the felspars contain large enclosures of the ground mass which have not entirely separated from the main mass; whilst the dusty appearance described in the previous pages is very prominent in the felspars of this slice. In some cases it makes them resemble nepheline, but the angle of extinction and the twinning of the sanidine and plagioclase (for the dusty appearance is seen in both classes of felspars) usually prevent any mistake in their identification.

The ground-mass contains granules of greenish hornblende, whilst minute four and six-sided well-shaped prisms of a brownish hornblende project from

the ground-mass into the vesicular cavities. The prism of one measured exactly 124°, 30 .[1]

Apatite is present, also magnetite and hæmatite or göthite. There are also several large and small crystals of the orange red mineral, previously described. Between crossed nicols it changes from a rich crimson colour to dark.

Several of the vesicular cavities are stopped with calcite.

No. 17.—A greenish-grey fine-grained but highly vesicular lava, from the vicinity of the Station Point Cemetery. It is distinctly magnetic and fuses at the edges under the blowpipe. The siliceous globules are abundant.

M.—This is more uniformly vesicular than the last specimen, and the vesicular spaces occupy a considerable area relative to the ground-mass; consequently very large crytals of felspar are wanting and medium-sized ones are comparatively rare. In other respects this specimen closely resembles the last.

There are siliceous globules, as in the last, but tridymite is also abundant and occurs on the edges of the vesicular cavities. An overlapping of the plates is an almost constant feature in the tridymite of this and other slices. The vesicular cavities are occasionally plugged with a fibrous zeolite.

The red mineral is absent and the brown hornblende, of the last specimen, is extremely sparse. Green hornblende in acicular prisms is very abundant.

Trachytic Pitchstones.

No. 18.—A compact brick-red lava with facets of felspar visible here and here. From the vicinity of the Station Point Cemetery. Sp. G. 2·40. The rock is magnetic and fuses, but not very readily, to a white blebby mass full of air bubbles.

M.—The ground-mass is of such microscopic fineness that it requires powers of over 100 diameters to make it out. It consists of a matted mass of felspar microliths and fine granular matter. In this are scattered felspar crystals of various sizes, some hornblende and large magnetite grains. None of the felspars give evidence of being triclinic. The large felspar crystals contain numerous enclosures of the base. The slice contains countless crystallites of felspar that closely resemble those described in my paper on the basalts of Bombay,[2] having either frayed ends, or being mere skeletons enclosing the granular matter of the ground-mass.

Hyalites are to be seen in a few vesicular cavities; their outlines are semicircular.

This vitreous lava may, I think, be described as a devitrified trachytic pitchstone. A sketch of a portion of this slice is given at fig 3.

No. 19.—A reddish compact rock from the vicinity of the Station Point Cemetery. Sp. G. 2·38. This looks more like a rotten schist than a lava. Though not visibly porous or vesicular, yet when plunged into water it gives off a stream of minute air bubbles that lasts for some hours. It is not magnetic. Under the blowpipe it fuses with difficulty and becomes frothy.

M.—The ground-mass consists of micro-crystals of felspar interspersed with

[1] Rutley's Study of Rocks, p. 152, 2nd Ed. [2] Records, Vol. XVI., p. 42.

micro-grains of quartz, and an amorphous opaque red ferrite. It is of muc larger grain than the last specimen.

All the porphyritic crystals of felspar are sanidine. They contain stone an glass enclosures. One of the latter is depicted at fig. 14, and is seen to contai three fixed bubbles and three crystals. Fig. 15 represents a cavity within a gla enclosure; the outer glass enclosure containing a large fixed bubble and a sma crystal. The inner cavity appears to contain a minute bubble. Enclosures th have deposited dusty matter on cooling; and glass enclosures, each of which con tains a large fixed bubble, are not uncommon. The slice contains no hornblend

This lava seems to be intermediate between a quartz-trachyte and a pitcl stone, but must, I think, be classed as a devitrified trachytic pitchstone.

Pumice.

No. 20.—A light grey pumice obtained in the vicinity of the Station Poi Church.

M.—The vesicular cavities are filled with calcite, a zeolite, and I think som aragonite.

The pumicious part consists of a glass containing millions of air bubbles some of these are round, whilst others are elongated, and are drawn out in th direction of the flow.

Conclusion.

Though I cannot suppose that my collection of the lavas of Aden afford com plete examples of all the varieties to be obtained in the neighbourhood o that extinct volcano, still it is sufficient to show that the now silent crater in the days of their activity, poured out basic, intermediate, and acid lavas. W have presented to us inside the main crater of Aden an unbroken successio of lavas, from acid pitchstones, on the one hand, to basaltic rocks on the othe Pitchstones shade into quartz-trachytes; quartz-trachytes into trachytes; whils the latter pass into andesites, and through them, into basalts. On the whole, th acid rocks seem to have predominated.

Many of the lavas described in these pages have a mottled, and even a brecci ated appearance, and it is difficult to say positively whether this is due to segre gation, or to an imperfect blending of basic and acid magmas.

It would be interesting to know the order of succession in which the basic intermediate, and acid lavas appeared; but on this point I have no information.

The specific gravity of each class of lava is low. I did not attempt to deter mine the specific gravity of the vesicular specimens, and though it is possible tha hidden vesicles may, to some extent, have vitiated the determination of the specifi gravity of some of those examined, yet, on the whole, I am disposed to attribut the low averages to the predominance of the acid element in the Aden lavas.

The following averages were obtained:—

Basalt	Sp. G.	2·78
Andesite	„	2·62
Trachyte	„	2·58
Quartz-Trachyte	„	2·55
Pitchstone	„	2·39

The pitchstones yield a somewhat abnormally high specific gravity, indicating their connection with the quartz-trachytes; but all the others, noted above, though within the minimum limits, are below the normal *average* specific gravity usually given for each class of rock in our text books.

The ground-mass of the intermediate and acid lavas, described in these pages, is micro-aphanitic; in no instance is it micro-felsitic. There are, except in the extremely vesicular specimens, and in the pitchstones, always three generations of felspar; micro-crystals in the ground mass, and medium and large-sized porphyritic crystals.

In the basalts and andesites the felspar is, almost without exception, plagioclase. Amongst the trachytes, those on the border line of the andesites, as No. 9, contain more porphyritic crystals of plagioclase than of sanidine; whilst those that approach the quartz-trachytes contain scarcely any plagioclase.

In intermediate varieties, as Nos. 8 and 10, the porphyritic crystals of triclinic and monoclinic felspar are pretty equal in number. In the quartz-trachytes, themselves, plagioclase is either wanting or is subordinate to the sanidine; whilst in the pitchstones plagioclase is wholly absent.

Augite is prominent in the basaltic lavas, but only stray crystals of it are present in the other lavas, namely, in Nos. 6, 9, 10, and 13.

Hornblende is abundant in the trachytes and in most of the quartz-trachytes; whilst it is sparse or wanting in the pitchstones.

Magnetite is present in all except No. 20, and every specimen, except Nos. 19 (pitchstone) and 20 (pumice), distinctly attracts the magnetic needle; some of them acting powerfully on it.

Hematite or göthite is found in all the specimens except the pumice; whilst apatite is commonly present, sparsely in some, but abundantly in others.

An isotropic mineral which I doubt not is garnet is to be seen in several slices, namely, in Nos. 8, 9, 12, and 14.

There is nothing in the appearance of the mineral to lead me to suppose that it is hauyne, a mineral frequently mentioned in connection with trachytes. Zirkel, in his Microscopic Petrology of the Fortieth Parallel, notes the occurrence of garnet in rhyolites and trachytes; and seeing that this mineral so commonly occurs in granite and syenite, its presence in the lava form of those rocks is hardly surprising.

Mica is conspicuous by its absence; but there is, however, a notable exception in slice No. 11 (quartz-trachyte), in which a thin string of crypto-crystalline mica, similar to that which takes so prominent a place in the gnëissose granites of the North-West Himalayas,[1] is seen meandering through the slice. This link between acid volcanic and acid plutonic rocks seems to afford an indirect confirmation of the correctness of the conclusion regarding the affinities of the gneissose granite arrived at on other grounds.

Stone and glass enclosures are common in the felspars; also cases of magnetite forming upon and embracing microliths in a way that indicates a viscid, or

[1] Records, Volume XVI, p. 129.

fused, condition, and consequent freedom of molecular action,—facts which also form interesting points of contact with the gneissose granite of the Himalayas.

The general absence of fluid cavities is generally considered characteristic of the quartz of lavas, as compared with that of granite; but exceptions to this rule do not appear to be altogether uncommon. Dr. Sorby notes one in his Ann. Address, Q. J. G. S XIV. p. 84; another instance will be given in my forthcoming paper on the Traps of Dalhousie; whilst yet another will be found in this paper in my description of slice No. 15.

EXPLANATION OF THE ILLUSTRATIONS.

Fig. 1.—A quartz-trachyte, slice No. 13. The central felspar is imperfectly formed, and contains enclosures of the ground-mass.

Fig. 2.—A trachyte, slice No. 9; with a group of felspar crystals, in the centre of the field, round which magnetite and ferrite have collected. The felspars enclose portions of the ground-mass alligned in general correspondence with the direction of cleavage.

Fig. 3.—A devitrified trachytic pitchstone, slice No. 18.

Figs. 4 & 5.—Stone enclosures, slice No. 13.

Fig. 6.—Enclosures in felspar of slice No. 13. The matter deposited is partly mineral and partly gaseous.

Figs. 7 & 8.—Stone and glass enclosures that have deposited mineral matter on cooling.

Fig. 9.—A glass cavity taken from slice No. 12 which contains an enclosure of gas.

Fig. 10.—A stone enclosure, slice No. 12.

Figs. 11, 12, & 13.—Magnetite and opacite forming on belonites.

Fig. 14.—Glass enclosure, slice No. 19, containing crystals and fixed bubbles.

Fig. 15.—A glass cavity containing an inner enclosure, slice No. 19.

Fig. 16.—An enclosure taken from No. 12, which has deposited mineral matter and also contains gas.

Note on the Probable Occurrence *of* Siwalik Strata *in* China *and* Japan. *By* R. LYDEKKER, B.A., F.G.S., F.Z.S.

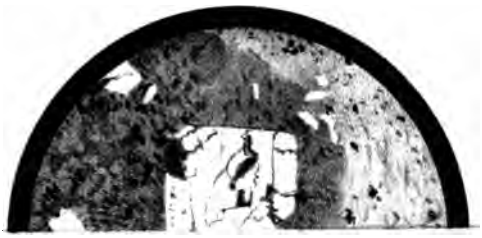
I have lately received from Herr L. v. Loczy, of the Royal Geological Survey of Hungary, a letter in which I am informed that during a recent expedition to China he observed extensive tertiary formations on the Upper Hwangho (Hoang-ho) river, in which he collected fresh-water shells and numerous bones of Proboscidia and Rodentia[1] (*sic*). In Western Kansu[2] he acquired from a native dispensary other large fossil bones, and the lower molar of an elephant which he considered very similar to the teeth of the Siwalik *Stegodon clifti*; this molar

[1] ? Ruminantia.

[2] A province on the Upper Hwangho, due north of Burma.

GEOLOGICAL SURVEY OF INDIA

McMahon: Aden lavas. Records Vol XVI.



CORRIGENDA *and* ADDENDA *to* "SYNOPSIS *of the* FOSSIL VERTEBRATA *of* INDIA." *Supra, pp. 61—94.*

N. B.—It is to be regretted that Mr. Lydekker could not correct the proof sheets of his paper. Most of these corrections are such as only the author could make.—H. B. M.

Page 62, 86. The *Cochliodontidæ* (*Poecilodus* and *Psephodus*) should be referred to the *Ganoidei*.
" 63, line 8 from top, for *Oxychina* read *Oxyrhina*: the genus *Sphærodus* should be referred to the *Ganoidei*.
" 65 " 21 " bottom, for *barioccipital* read *basioccipital*.
" 66 " 4 " top, " *centre* read *centra*.
" 69 " 14 " bottom, before *British Museum*, add *Royal College of Surgeons and*.
" 70 " 3 " " for *two* read *three*: in the following line *dele* '*and a mandible*.'
" 71 " 1 " top, " *Enhydras* read *Enhydris*.
" 72, note, for *irvaticus* read *iravaticus*.
" 74, line 19 from top, for *H. hyopotamoides* read *A. hyopotamoides*.
" 76 " 11 " " " *acuticornis* read *porrecticornis*.
" 77 " 10 " " " *Nilgherries* read *Himalaya*.
" 80 " 2 " bottom, *dele* '*south*.'
" 81 " 3 " top, for *when* read *whose*.
" 85 " 1 " bottom, for *Eg.* read *Münst*: also on p. 87, line 12 from bottom.
" 86 " 4 " top, before *Sphyrænodus* add *Teleostei*.
" " " 5 " " below *Pycnodus*, add *Sphærodus rugulosus*, Eg.: this should also be inserted in the alphabetical list.
" 88 " 20 " " for *dhonkoka* read *dhongoka*.
" 92 " 17 " bottom, for *Typholodon* read *Typhlodon*.
" " " 8 " top, " *predicus* read *indicus*.

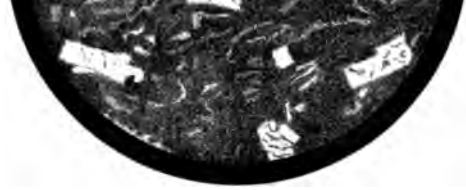


Fig. 3 × 30

J. Schaumburg, Lith. Printed at Geol. Survey Off.

fused, condition, and consequent freedom of molecular action,—facts which also form interesting points of contact with the gneissose granite of the Himalayas.

The general absence of fluid cavities is generally considered characteristic of the quartz of lavas, as compared with that of granite; but exceptions to this rule do not appear to be altogether uncommon. Dr. Sorby notes one in his Ann. Address, Q. J. G. S XIV. p. 84; another instance will be given in my forthcoming paper on the Traps of Dalhousie; whilst yet another will be found

(Hoang-ho) river, ...

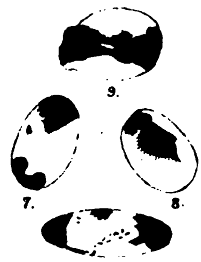
Proboscidia and Rodentia[1] (*sic*). In Western Kansu[2] he acquired from a native dispensary other large fossil bones, and the lower molar of an elephant which he considered very similar to the teeth of the Siwalik *Stegodon clifti*; this molar

[1] ? Ruminantia.

[2] A province on the Upper Hwangho, due north of Burma.

Fig. 1. × 30

4. 5. 6.



7. 8. 9. 10.

Fig. 2 × 30.

12 13

14. 15. 16.

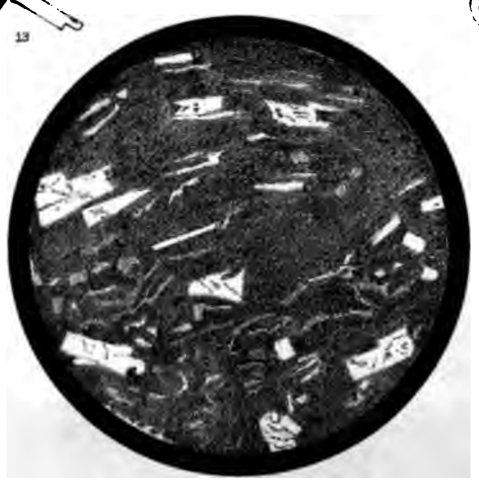


Fig. 3 × 30

is described as being brown and highly mineralized, and apparently in very similar condition to the Siwalik fossils.

I am promised an opportunity of examining a cast of the molar, but the description given leaves little doubt that the strata whence the fossil was obtained correspond to the Siwaliks. It will be remembered that Professor Owen has described [1] the milk-molar of a *Stegodon*, said to have been obtained from "marly beds near Shanghai," which he referred to a new species under the name of *S. sinensis*, but which I have seen [2] no reason to separate from the Siwalik *S. clifti*. The mineralization of this specimen (now in the British Museum) is precisely similar to that of the Siwalik fossils, and leads me to conclude that the beds from which it was obtained, together with the Hwangho beds, almost certainly correspond, at least in part, to the Siwaliks. The geographical position of the Hwangho beds, due north of Burma, lends a strong support to this conclusion, as it is well known that the Siwaliks of that country, whence Crawfurd's original specimens were brought, extend far up the valley of the Irawadi, and thus are only separated by Yunan and Sechuen from the Kansu district.

In the same paper Professor Owen also described various other Chinese fossil mammals, belonging to the genera *Chalicotherium*, *Rhinoceros*, *Tapirus*, *Stegodon*, and *Hyæna*, and said to have been obtained from a cave in the province of Sechuen (Sze-chuen), or between Kansu and Yunan and Burma. The mineralization of these specimens is much less complete than that of the Shanghai and Siwalik fossils, but the difference in the manner of the entombment of the specimens is probably quite sufficient to account for this. The genera are all characteristic of the Siwaliks, and although Professor Owen has assigned all the specimens to distinct species, yet it has appeared to me [3] to be highly probable that the *Stegodon* is the same as one of the Siwalik forms; while work on which I am now engaged leads to the conclusion that the Sechuen hyæna is identical with, or very closely allied to, one of the Siwalik hyænas. Whether or no the species be the same, it appears to be most probable that the Sechuen mammals belong to the same period as those of the Siwaliks, and connect those of Burma with those of Kansu.

Turning to Japan, it may be observed that in 1881 Dr. Edmund Naumann figured and described [4] various remains of fossil elephants from that country, which he referred to the following species, *viz.*, *Stegodon clifti*, *S. insignis*, *Elephas namadicus*, and *E. primigenius*; the two first being Siwalik species, the second (or the allied *S. ganesa*) also ranging up into the Narbada beds, and the third being characteristic of the latter. These fossils indicate pretty conclusively that representatives of the mammaliferous beds of India, which probably correspond both to the Siwaliks and the Narbadas, exist in Japan, and are probably the continuation of the Chinese deposits.

[1] "Quar. Jour. Geol. Soc," Vol. XXVI, p 417.

[2] "Palæontologia Indica." Ser. X, Vol. I, "Siwalik and Narbada Proboscidia."

[3] *Ibid.*

[4] "Ueber japanische Elephanten der Vorzeit." 'Paläontographica,' Vol. XXVIII, pt. 1, pls. I—'II.

Since the publication of Dr. Naumann's memoir, another paper on the sa subject has appeared by Herr D. Brauns,[1] which is certainly a very remarkal paper indeed. In that paper it is first of all attempted to prove that t Siwaliks are entirely of miocene, and the Narbadas of pliocene age, wh the Japanese (and presumably the Chinese) mammaliferous deposits are referred to the pleistocene. Now it is not my intention on the present occasi to go again into the question of the age of the Siwaliks and Narbadas, but the are two points in relation to Herr Brauns' treatment of this question, to whi it is almost impossible to omit referring. It happens to be inconvenient to l line of argument that any of the Siwalik species should occur in the overlyi Narbadas, and therefore, when such is stated to take place he adopts the very eas but scarcely scientific, method of doubting the evidence. Thus in the case the occurrence of *Stegodon insignis* (or the allied *S. ganesa*) in the Narbadas, it stated[2] that the two specimens of broken teeth figured in the "Fauna Antiq Sivalensis[3]" from those deposits are not sufficiently perfect for determinatio and therefore that *S. insignis* does not exist in the Narbadas. Even if the specimens are insufficient evidence, if the author had but taken the trouble refer to page 117 of the first volume of the "Palæontological Memoirs," he wou have seen a very perfect specimen of the lower jaw of *S. insignis* (No. 1) fro the Narbada described by Dr. Falconer; this specimen, which is now in the Indi Museum, where there are others from the same beds, leaves not the slightest dou that *Stegodon insignis* (or *S. ganesa*, which, as far as teeth are concerned, is t same) occurs in the Narbadas. From this may be gathered the value of t following dogmatic statement of Herr Brauns, *viz.*,—

Elephas namadicus	solely pliocene,
Stegodon insignis	" miocene.
" clifti	" "

In the case of the occurrence of the Narbada *Bubalus palæindicus* in the to most Siwaliks, it is argued that the specimens are not properly determined. happens, however, that they are unquestionably the same as the Narbada speci I have not figured them because there are so many other specimens of mo importance. Similarly doubt is thrown upon the authenticity of the stone impl ments from the Narbadas. If this sort of reasoning be allowed, of course an thing can be proved.

Leaving now the Narbadas and Siwaliks which Herr Brauns has proved his own satisfaction are respectively pliocene and miocene and contain species in common, attention may be re-directed to the Japanese fossils. Co sidering, as Herr Brauns does, that the beds from which these fossils we obtained are entirely pleistocene, and therefore altogether newer than the Siwalil and the Narbadas, it would never do that any of the fossils from them shou

[1] "Ueber japanische diluviale Säugethiere," Zeits. d. Deutsch. Geol. Gesell., 1883, pp. 1—83.

[2] *Ibid*, p. 9.

[3] Pl. 56, figs. 10, 11.

be the same as those of either of the latter. Accordingly the fossils described and figured by Dr. Naumann are re-named as follows, *viz.*—

Elephas meridionalis, Nesti, = *Stegodon insignis*, Naumann, pls. 3-5.
Elephas antiquus, Falc. = *Elephas namadicus*, Naumann, pls. 6-7.
Stegodon sinensis, Owen = *Stegodon clifti*, Naumann pls. 1-2.

Now there is not the slightest shadow of a doubt that the specimens figured by Dr. Naumann under the name of *S. insignis* are true Stegodons, and belong either to the Siwalik *Stegodon insignis* or *S. bombifrons;* they have nothing whatever to do with a *Loxodon* like *E. meridionalis.* The molars of *E. antiquus*[1] and *E. namadicus* are so alike that it is difficult or impossible to distinguish them, and there is therefore at least a probability that Dr. Naumann's determination may be correct. The specimen figured by Dr. Naumann as *Stegodon clifti* is a typical specimen of the last lower molar of that species, like many in the Indian Museum. I can see not the slightest reason why this tooth should be associated with the Shanghai milk-molar of the so-called *Stegodon sinensis* and so separated specifically from *S. clifti* of the Siwaliks.

There accordingly seems not the slightest doubt but that Dr. Naumann is perfectly correct in referring two of the fossil Japanese elephants to Indian Siwalik species; while it is not impossible that a third is a Narbada form; a fourth species is, however, referred to the European and North American *Elephas primigenius*, and to this Herr Brauns adds the European *Bison priscus*, Bojanus.

These determinations lead to the conclusion that the mammaliferous beds of Japan in all probability correspond both with the Siwaliks and Narbadas of India (which may there be in normal sequence), with the former of which they are connected by the Shanghai, Kansu, Sechuen, and Burmese deposits; and that they also contain an admixture of European palæarctic forms, which have probably reached Japan through northern America. In place of the fauna of the Japanese beds being distinct from that of the mammaliferous beds of India and affording any argument for the latter being pliocene and miocene in place of pleistocene and pliocene, all the evidence points very strongly to the equivalency of the two, and to the confirmation of the latter view of their age.

The Lodge, Harpenden, Herts.

Note on the Occurrence of Mastodon angustidens *in* India. *By* R. LYDEKKER, B.A. *&c., &c.*

Several specimens of the "intermediate molars" of a trilophodont mastodon collected by Mr. W. T. Blanford in the lower Manchhars (Siwaliks) of the Dera Bhugti country (Eastern Baluchistan), are absolutely indistinguishable from the corresponding teeth in the British Museum of *Mastodon angustidens*, Cuvier, of the upper miocene of Europe.

The occurrence of a European species of mastodon on the extreme western

[1] I am indebted to Herr Brauns for pointing out that in "Siwalik and Narbada Proboscidia" I have inadvertently given the age of *Elephas antiquus* as pliocene instead of pleistocene.

limits of India is a fact of great importance, indicating that we may look for a commingling of the faunas of the Siwaliks, and of the European upper miocene and lower pliocene in Persia and Asia Minor.

These important and interesting specimens will be figured in the "Palæontologia Indica" at no very distant date.

Notes on a Traverse between Almora *and* Mussooree *made in October 1882 by* R. D. OLDHAM, A.R.S.M., *Geological Survey of India.*

The following notes were made on a rapid tour between Almora and Mussooree during the month of October last; they cannot of course pretend to be a detailed description, but are of some interest in view of the question of the continuity of the Himalayan rocks in the Almora and Simla regions.

At Almora the rocks are gneiss and schists of various descriptions, lying nearly horizontal on the east of the Kosi, but on the ascent to Bainskhet the dip increases to 45°, the direction being N. 10° E., a dip which continues steady in direction, though varying in amount, till the Gagas is reached. Here the road runs over alluvium for a couple of miles, but rock again shows up on the hill called Buridunga; it is a porphyritic gneiss, similar in structure to the central gneiss. As the road runs near the northern boundary of this exposure cutting across it in several places, it is seen to be fairly straight and presumably a fault, the schists in contact with the gneiss dipping south-south-east; at Dwarahat, where the road cuts across the exposure here not a mile broad, the dip of the foliation of the gneiss has bent round to south-west and, though I was not able to trace the gneiss further to the north-west, I have no doubt that it does extend along the ridge since in the streams flowing down to the Khurrogadh blocks of it are not of infrequent occurrence.

Along the road between Dwarahat and Ganain the only exposure of slates seen was below Naugaon on the south-west side of the valley where they dipped W. 30° S., while near Ganain the dip was south-west.

On the eastern side of this valley, the ridge is capped by limestone (krol), which, apparently forming the peak of Dunagiri, descends further north, at the village of Damtola, almost to the bottom of the valley, and is seen to extend northwards from Ganain as far as the eye can reach, being confined to the eastern side of the valley with the exception of two patches capping the spurs above Bushbira and Naugaon respectively. As is generally the case, no dip was accurately determinable in the limestones, but they evidently dip somewhere about north-west.

Beyond Ganain, where the road leaves the alluvium, slates come in with a dip to W. 10° N. and on the ascent become more and more schistose; the dip at the same time becoming flatter, till near Jaurasi the porphyritic gneiss again comes in with almost horizontal foliation; this is not improbably a continuation of the Dwarahat exposure.

The gneiss continues to near Bongdhar, the only interruption being below

the Makroli hill, where a narrow strip of black crush rock is let down by faulting. Near Bongdhar the slates come in again, at first with a N. 50° E dip at 45°, but this soon bends round to the normal N. 10° E. dip, the schistose slates continuing beyond this with a dip varying between N. 10° E. and N. 30° E.; at the bridge over the Nyar a thin band of porphyritic gneiss, probably here merely a more metamorphosed band among the schists, is exposed; opposite Gwalkura quartzites overlie the slates and continue to the bridge between Chifalghat and Pauri. On the crest of the ridge crossed on the road to Pauri quartzose rocks come in again, while beyond this the slates are much disturbed, but keep a pretty steady E. 10° N. and W. 11° S. strike.

Beyond Srinagar there is not much of interest to note; the quartzites show up on the ridge below Maniknath which is itself capped by limestone, but for the most part the rocks are of a recognisable infra-krol type.

Beyond Tiri, where the road runs along the Mussooree ridge infra-krols, quartzites, limestone (krol) and in one place the Blaini are seen, but the structure, as is the case everywhere on the outer ridge, is far too complicated to be unravelled by a simple traverse along the strike of the rocks.

I have reserved for separate notice the alluvial deposits, of which I shall now mention the more important.

Between Bainskhet and Dwarahat near the village of Kapalna the road runs along the surface of an old lake deposit, of which a narrow strip has been left uneroded, the streams on either side having cut deep into the deposits; in both the other valleys crossed before reaching the Gagas traces of extensive deposits are seen but forming a mere skin on the rocks below, having been almost entirely removed by the streams. At Kapalna the gradual raising of the deposits has given the drainage an easier escape over a saddle in the watershed into the next valley to the west; hence the lower part of the deposit has been exposed to the erosion of its own drainage only, while in the other valleys the streams flowing down from the hills to the north have almost entirely washed away the alluvium.

In the Gagas valley there is another alluvial deposit, which, having come mostly from the hills to the west, has by its slope forced the river to the eastern margin of the plain, where it has now cut for itself a new channel in the solid rock of about 60 feet in depth.

This deposit extends up the Pokhy valley, and some of the drainage of its western extremity flows into the Chundas. Here again there has evidently been a diversion of the drainage, due to the gradual raising of the surface of the alluvium to the level of one of the saddles in the original watershed.

Near Dwarahat there is another broad expanse of lacustrine deposits situated at the head of the Baiaru river. These deposits which, be they lacustrine or no, are at any rate formed in true rock basins situated at the very heads of the drainage areas, and rising almost to the level of the watershed have never, so far as I am aware, been adequately explained. They are by no means of merely occasional occurrence, but are scattered throughout these hills; one very good example being at the head of the Blaini river near Solan on the Simla road.

The three rivers which meet at Ganain have all broad alluvial bottoms, part being close down to the present level of the streams, the rest forming a terrace raised some 30 to 60 feet, but the low level ground seems to be merely due to the erosion of the stream, and not to a more recent deposition.

Near Ganain is a very interesting lake known as the Turag Tal; it is situated at the head of one of the streams flowing down to Gunain. In the valley of this stream an alluvial flat extends right up to the foot of the barrier, which is most clearly a landslip, for not only is the gap in the hill from which it has descended most evident, but the only other possible explanation, *viz.*, a moraine, is at once barred by the absence of any other rock but limestone in the barrier which is composed entirely of fragments and not of rock *in situ*. Above the barrier is a broad alluvial surface, the lower end of which is covered by water probably not of any very great depth. The level of this alluvium is about 200 feet above that in the valley below the barrier which itself rises 50 feet above the upper alluvium; the total depth of the landslip is therefore 250 feet, and the time that has elapsed since its fall has been that required for the formation of alluvium 200 feet in thickness.

Near the head of the Binan river there is a small deposit of alluvium as also at Chopryon and Kandura near Powri.

At Srinuggar and Tiri there are extensive terraces covered with a thin coating of river gravel, but in the main merely carved out of the solid rock.

The above-mentioned alluvial deposits are all in true rock basins, but only the three first mentioned, *viz.*, those near Kapalna, in the Gagas, and at Dwarahat, seem, from their uniformity and fineness of texture, to be of lacustrine origin.

Though there was never much doubt as to the propriety of correlating the rocks on the Almora section with those of the Simla region, such shadow of it as there was may be held to be now dispelled, for in the region crossed between Almora and Mussooree the rocks are seen to become gradually less metamorphic, and the distinctions of the sub-divisions but obscurely seen near Almora become more and more marked till the rocks assume the normal character which they are found to maintain from Mussooree to the north-west.

Note on the Cretaceous coal-measures *at* Borsora *in the* Khasia Hills, *near* Laour *in* Sylhet, *by* TOM D. LA TOUCHE, B.A., *Geological Survey of India.*

I have visited and examined a section of the coal-bearing rocks situated at the foot of the Khasia Hills to the north of the district of Laour.

Position of the section.

The section examined occurs in a ravine, at the mouth of which stands the Garo village of Borsora, about 5 miles west of the point where the Panatibh or Jadukhata river leaves the hills. At the edge of the plains on either side of this village nummulitic limestone is exposed dipping to south-south-east or towards the plains at an angle of 38°.* On proceeding up the ravine along a path on the west side of the stream no sections of rock *in situ* are seen, but the path is covered with blocks of

* From this a large amount of stone has been quarried by Messrs. Inglis & Co.

a coarseish yellow and brown sandstone. The path rises for about half a mile until the mouth of a small steep ravine on the west is reached, in the sides of which the coal seams are exposed.

Description of the section.

At the junction of the two ravines carbonaceous shale is seen in the bed of the stream dipping to south-south-east at an angle of 12°. Upon this rests a seam of good coal 3 feet 10 inches thick extending for about 20 yards along the side of the ravine. This is overlaid by 5 feet of shaly sandstone, upon which rests a second seam of coal 3 feet 4 inches thick. This seam has been disturbed by several small faults or slips, and parts of it have been denuded to some extent before the deposition of the overlying sandstone, so that its thickness is not so constant as that of the lower seam. Proceeding up the ravine about 60 feet of fine yellow sandstones are passed over, and a third seam of coal is met with, cropping out on both sides of the ravine. The thickness of this seam could not be determined exactly, as a small landslip has occurred in the rocks above, and has partly covered it, but it is at least 4 feet thick, though not quite free from shaly partings. Above this the ground is covered for 50 or 60 feet with the debris from the slip above mentioned, consisting of fine yellow sandstones and shales with many fragments of coal, and above this again, at the top of the section, is a fourth seam, of shaly coal, 2 feet thick. In the whole section therefore of about 150 feet there are about 12 feet of good coal, distributed in three seams as shown below, in descending order :—

		Ft.	*Ins.*
Shaly coal	about	2	0
Fine yellow sandstone and shale	"	60	0
Coal seam, No. 3	"	4	0
Fine yellow sandstone	"	60	0
Coal seam, No. 2	"	3	4
Shaly sandstone	"	5	0
Coal seam, No. 1	"	3	10

Carbonaceous shale, thickness unknown.

TOTAL	"	138	2

Quality of the coal.

The coal of seams Nos. 1 and 3 is much disintegrated by exposure, so that it is difficult to get good specimens for analysis, but it appears to be a very good coal, with a bright fracture and black colour, containing numerous specks and nests of a kind of fossil resin. This resinous substance, which is characteristic of the coals of this region occurring in cretaceous rocks, together with the position of the seams below the nummulitic limestone, shows that the coal is of the same age as that of the Garo hills and the small basin at Maobelarkar, and is therefore distinct from the coal of Cherra Poonjee, which occurs above the limestones. The coal of seam No. 2 is more compact and browner in colour, and is traversed in all directions by small joints.

It also contains specks of the fossil resin. Samples assayed in the Survey laboratory by Sub-Assistant Hira Lal gave the following satisfactory results:—

	Seam.	
	No. 1.	*No. 2.*
Moisture	5·84	3·02
Other volatile matter	35·16	39·58
Fixed carbon	50·40	50·80
Ash	8·60	6·60
	100·00	100·00

No. 1 does not cake; ash pale red.
No. 2 cakes; ash red.

Probable extent of the field.

The section examined is very similar in some respects to one described by Captain H. H. Godwin-Austen (Jour. As. Soc. Bengal, Vol. XXXVIII, Pt. II, No. 1, 1869) as occurring on a small tributary of the Umblay near the village of Nongkerasi, about 10 miles to the north-west of Borsora; but to determine whether the coal-measures are continuous between these points would require a more detailed examination of the district than I was able to make. The only means of getting sections in such a country is to follow up the hill streams in which fragments of coal are found to the outcrop of the seam, and at this season (June) these streams are liable to sudden floods and become quite impassable. If it should be found that the coal does extend between these points, its amount must be very large.

Position of the seams as regards extraction of the coal.

The outcrop near Borsora is very favourably situated for being worked. It is not more than half a mile within the hills and at a low elevation above the plain. The coal rises from the outcrops so that mines or quarries could be easily drained. The foot of the hills is only 1 mile from the Patlai river, a branch of the Jadukhata, and during the rains boats can come up to within a few hundred yards of the hills.

Even now great numbers go close to the spot during the rains to carry away limestone from the numerous quarries between Borsora and Lakma.

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RECORDS

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Part 4.] 1883. [November.

Palæontological Notes from the Daltonganj *and* Hutar coalfields *in Chota Nagpur, by* OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

THE above two coalfields were surveyed by Messrs. Hughes[1] and V. Ball[2] respectively, but no fossils were known from either of them. It was, however, of interest to ascertain whether fossils occurred there and of what character they were, as it was quite to be expected that some portion of the coal beds in one or the other might be of the age of the Karharbári beds. I was consequently last winter deputed to visit these coal-fields and to examine them for fossils. The results were satisfactory enough, as not only were fossils met with in good numbers, but they were also sufficiently clear to allow of some of the horizons being fixed with much probability.

The Daltonganj coalfield.

This coalfield is situated about 50 miles west of Hazáribágh, and is traversed by the Koel and Amánat rivers. The rocks represented in the coal-field are the Talchirs and the coal-measures. These were hitherto assigned to the Barákar group of the Damuda subdivision of the Gondwána system. The examination of the fossils, however, showed that these coal beds of the Daltonganj field most probably are of the age of the Karharbári beds.

The various outcrops in this field are described in Mr. Hughes' report; I visited most of them with the view of examining them for fossils.

Outcrops at Singra.

At the junction of the Koel and Amánat rivers, about 5 miles north of Daltonganj, near Singra, where mining is carried on to some extent, there is a good exposure of the coal-bearing rocks, consisting of sandstones and sandy shales, with three outcrops of coal seams.

The base of the section close to the river surface consists of a series of sandy micaceous grey shales, which are on the whole unfossiliferous; but very

[1] Mem. G. S. I., Vol. VIII, Pl. 2.
[2] *Ibid*, Vol. XV, Pl. 1.

nearly at the base there is a stratum in which some leaf impressions occur; they are not very distinct, though the following can be recognised :—

Gangamopteris cyclopteroides var. *attenuata.*
Glossopteris communis, Feistm; large leaves.
" *indica*, Schimp.

The stratum immediately above this bed contains root-like impressions traversing the rock in various directions; in some cases they appeared to me to be of *Vertebraria.* Above this bed is the coal outcrop, representing the first seam of the series.

Above this follows a series of sandstones and shales, without any trace of fossils, underlying the second seam. Above this seam there follows a series of grey sandy shales, with a band of hard and light grey shale.

The third seam, which now follows, is not exposed in this section on the river, but a little further to the south. In a soft fine shale, of grey colour with reddish tints, above this seam the following fossils were found :—

Vertebraria indica, Royle.
Nöggerathia hislopi, Bunb. (Feistm.); numerous.
Samaropsis parvula, Heer.
Seeds, may be of the foregoing species.

These fossils, though not very numerous or quite decisive, yet show an ensemble like those from the third Karharbári seam or from the Mohpáni coal seams, both of which, there is little doubt, belong to the Karharbári beds.

This Karharbári character of the fossils is, however, more distinctly expressed in some other outcrops to the north of Singra.

Outcrops at Rajhera.

There is no mining carried on at present at this place, though there are traces of old workings; there is, however, no want of outcrops, one of which yielded a good number of fossils.

In a nala to the south of Rajhera there are at first sandstones like those above the first seam at Singra. Lower down below the sandstones there is an outcrop of grey sandy micaceous shales, about 5 feet thick; in about the middle of these shales, and I think representing the coal outcrop, is a band of a darker shale, which breaks irregularly, with somewhat a sphæroidal structure. I think this outcrop represents the first seam of Singra.

The above-mentioned dark shale band is full of leaf impressions, which are in most cases very well preserved, and amongst which the following species could be recognised :—

Glossopteris communis, Feistm.; very large leaves with a thick midrib and very close and narrow meshes.
Glossopteris indica, Schimp.
" *decipiens*, Feistm.; one specimen like the species from the Karharbári coalfield.
Gangamopteris cyclopteroides, Feistm. The true original form like in the Talchirs and Karharbáris; in various states of preservation, but also showing distinctly the basal portion.

Gangamopteris var. *subauriculata*; one nice specimen, with doubled up margin.
" var. *attenuata*.
Samaropsis, comp. *parvula*, Heer; just like some from the Karharbári beds.
Voltzia—a branchlet of a coniferous plant, belongs I think to this genus.

There are some other shale outcrops east of Rajhera, which, however, did not yield many distinct fossils, though the rock in which they occurred, a sandy shale of greenish-brownish colour with reddish tints, resembles one in the Mohpáni coalfield containing fossils of the Karharbári type. The only fossils in the present instance were: *Glossopteris communis*, Feistm., and *Equisetaceous* stems.

A comparison of the fossils named above with those from other coalfields will show that they bear the character of those known from the Karharbári beds, and there is little doubt that the coal seams of the Daltonganj coalfield, at least those where fossils were found (at Singra and Rajhera), are of the age of the Karharbári beds, which circumstance would perhaps add not a little to the importance of the coalfield.

The Hutar coalfield.

From this coalfield, which is situated on the Koel river to the south of the Daltonganj field, and which was surveyed by Mr. Ball, I have also brought a few fossils. I visited first the outcrops on the northern margin, south of the village Nowadih. Here the coal-bearing rocks are in contact with the Talchirs. Following a nala which joins the Supuhi river close to where the road from Daltonganj crosses the former, at first several outcrops are found between massive sandstones with a south-west dip; in these no fossils were found. Further on, close to the junction of the coal-bearing rocks with the Talchirs, there are other outcrops of strongly carbonaceous shales, quite close to the Talchirs, in which the following fossils were found:—

Gangamopteris cyclopteroides, Feistm.
" var. *attenuata*.

These carbonaceous shales pass without break into strata which belong to the Talchirs, and are conformable with the former; the rock is, however, not of the usual kind, being still somewhat carbonaceous shale, although undoubtedly already in the Talchirs; here also some fossils were found:—

Equisetaceous stems.
Gangamopteris cyclopteroides, Feistm.; typical form.
" var. *subauriculata*.

If we consider now these latter as belonging to the Talchirs, then the carbonaceous outcrops in close proximity to them are perhaps either of the same age, or else represent the Karharbári beds, while the higher outcrops would have to be considered as representing the Barákar group. This is the only locality where these relations could be recognised.

Further to east, at the village Hutar, there are again some outcrops, also apparently in conformity with the Talchirs; some fragments of fossils were found, but insufficient to determine the horizon; I should, however, feel inclined to consider them as Barákars.

Somewhat better fossils were met with near the east end of the field, north of Saidope. At the confluence of the Dauri and Ghorsam streams there is a great display of beds. At the bottom of the section close to the river surface is coal, over it lies coaly shale, then grey sandy shales, above which follow sandstones of yellowish and reddish colours.

The fossils occurred in the black coaly shale above the coal, and the following could be recognised:—

Equisetaceous stems; very numerous.
Glossopteris indica, Schimp.
" *damudica*, Feistm.
Coniferous branch like *Voltzia*.

To judge from these fossils, the outcrops can be considered as belonging with great probability to the Barákars, and the same appears to be the case with the other outcrops in the field, so that only on the northern margin of the field would the fossils allow of a more varied grouping of the beds.

Some of the fossils gathered on this occasion from the Daltonganj and Hutar coalfields will be figured in the Palæontologia Indica, together with some others collected on a previous journey in the Aurunga and Káranpura coal-fields.

On the altered basalts *of the* Dalhousie *region in the* North-Western Himalayas, *by* COLONEL C. A. MCMAHON, F.G.S.—(*With two plates*).

In my paper on the Geology of Dalhousie, I have already described the mode of occurrence of the rocks of the volcanic series in the Dalhousie area, and it only remains to note their petrological characteristics as seen in thin slices under the microscope.

Specimens from the Bagrár ridge.

No. 1.—A dull green amygdaloidal rock weathering to a light brown colour. Sp. G. 2·85. The amygdules are of small size and are composed of scolecite, delessite, and a red zeolite. A little iron pyrites is to be seen here and there.

M.—This slice closely resembles an undescribed specimen of the Darang traps. Augite is abundant, and is in irregular-shaped elongated pieces; none of it is fresh, and the felspar is also considerably kaolinised. Viridite is abundant, and the slice contains epidote in a granular form. Scolecite not only fills amygdules, but has replaced much of the original material in their vicinity.

No. 2.—A greyish-green amygdaloidal rock weathering to a light brown. Sp. G. 2·86. The amygdaloidal cavities are filled with quartz and scolecite, and specks of iron pyrites are to be seen here and there in the rock.

M.—The amygdules are composed of scolecite, quartz, and viridite, the latter containing many crystals of epidote. Cracks in the rock and in the amygdules are filled with viridite and a yellow substance resembling epidote. The viridite is of the serpentinous variety.

The augite is altered almost past recognition, but it can be doubtfully made out here and there with the aid of polarised light. The small felspar prisms

are still to be traced, but all signs of twinning has disappeared, and the felspars have been so eaten into, and replaced by the green alteration-product, that their outline is irregular. The whole rock is permeated through and through with this green product of alteration, and all the outlines of the original minerals have become confused and hazy. No trace of magnetite remains.

The quartz which occurs in the centre of an amygdule surrounded by scolecite has a dusty appearance, which on the application of high powers ($\times$ 300 to 500) is seen to be caused by a multitude of extremely minute liquid cavities, many of which have movable bubbles. The liquid in some of the cavities is red coloured. The quartz appears to have formed after the scolecite which lines the amygdaloidal cavities, as it conforms itself to the outward form of the scolecite crystals.

No. 3.—A grey-green compact rock. Sp. G. 2·81.

M.—This is quite a typical lava. The base which forms a prominent object in the field of the microscope is considerable in amount in proportion to the imbedded crystals, and probably constitutes more than one-half of the whole. It is greenish-white in reflected, and something between a brown and an olive green in transmitted, light. It is not at all dichroic, and it does not polarise between crossed nicols, but changes from dark to its natural colour, much light, however, being absorbed. Under high powers it is resolved into very minute granular matter. This base is evidently a partially devitrified glass and represents the residuum left uncrystallized owing to the rapid cooling of the rock.

In this base, besides the larger crystals to be described further on, minute crystals of felspar, often acicular in shape, are scattered about, which are I think very characteristic of a rapidly cooled lava. Some of them have enclosed portions of the base, as in fig. 7, plate II, whilst others are in skeleton or incomplete forms similar to those depicted at figs. 1, 3, 4, 5, and 6, which are given as samples only, the shape of these minute crystals being very varied.[1]

In this base, besides the minute crystals just described, comparatively large ones of felspar and augite are arranged in clusters and groups.

In my paper on the basalts of Bombay I described the penetration of felspar by augite and of augite by felspar as a structural peculiarity very characteristic of volcanic rocks. This structure is more than usually prominent in this slice; indeed a large proportion of the augite and felspar crystals are interlaced and intermixed in a way that is very striking, and is often very complex. It would seem as if the first formed crystals floating about in the fluid base before they attained any size were drawn together by mutual molecular attraction, and that

[1] Figs. 5, 7, and 10 closely resemble some of the figures depicted in fig. 4, plate XI, Zirkel's Microscopic Petrology of the 40th parallel. Zirkel considers the forms shown in fig. 3, plate XI of his work above quoted as "probably a felspathic crystalline product of devitrification." Unfortunately "devitrification," as at present used by microscopists, is a very ambiguous term; thus Mr. F. Rutley, in a paper published in the Q. J. G. S. XXXVI, 407, writes of a rock described therein: "In the first case, it may be regarded as an obsidian devitrified *at its birth*; in the second, as an obsidian devitrified *in its old age*." Does Zirkel mean that the skeleton crystals he describes are congenital or epigenital? If the latter, I think he has missed the point of the matter. I think these imperfect forms are the result of rapid cooling and correspond to the skeleton crystals of slags.

the growth of the crystals then went on side by side so rapidly that they embraced and interlaced each other in the act of crystallization.

At fig. 1, plate I, the sketch of a portion of this slice, magnified 30 diameters is intended to give a general impression of its appearance in the field of the microscope, and the way the imbedded crystals of augite and felspar group themselves together in the base—one long band of the associated minerals forming a sort of festoon across the centre of the field.

At fig. 2 of this plate I have given a sketch of another portion of the same slice, magnified 60 diameters. The singular way the augite has embraced the felspar prisms is shown in the sketch. The feathery kind of termination of some of the felspars reminds me of those shown at fig. 2, plate I, of the illustrations to my paper on the Bombay basalts, and suggests the feathery terminations, described by Dr. Sorby, of the felspar of slags.

Other illustrations of the intergrowth of augite and felspar are given at figs. 2, 8, 9, and 11, plate II.

In a previous paper I quoted a passage from Dr. Geikie on the Volcanic rocks of the basin of the Firth of Forth, showing how felspar prisms "shoot" through crystals of augite as though they were "intrusive." Such figures, as the extraordinary ones represented at figs. 9 and 11, plate II, certainly imitate "intrusion" in a remarkable way, and at first sight suggest the idea that the felspar must have filled cracks in the augite crystals at a period subsequent to the genesis of the augite; but, I think these singular appearances are simply due to the fact that the crystallization of both the felspar and augite proceeded rapidly at the same time, and that the supply of material for the formation of the two minerals fluctuated. It will be observed, moreover, in fig. 2, plate I, and in figs. 2 and 9 of plate II, that the felspar is attenuated in the centre of the augite and expands rapidly at the edges. I have observed this to be a general rule, and have seen many cases of it much more striking than those in the illustrations to which attention is directed; and I think this peculiarity shows that the augite did not crystallize around previously formed felspar prisms, but that the crystallization of the two minerals proceeded simultaneously, and that the supply of felspathic material was, for a time, cut off by the vigour with which the molecules of augitic matter came together.

In fig. 2, plate I, and figs. 1, 2, 3, and 9 of plate II, I have attempted to illustrate a tendency observable in felspar crystals to fray out at their ends, or rather to throw off long hair-like prisms or appendages. This peculiarity is another indication, I think, of rapid cooling, showing that as crystallization proceeded, the supply of material was cut off by the loss of perfect freedom of molecular motion consequent on cooling; hence these crystals were unable to assume a perfect crystallographic form.

I dwell upon these details at some length, because they are not without interest in themselves, and because it is chiefly by noticing characteristic structural peculiarities that we are able to distinguish between basic volcanic and basic plutonic rocks.

All the augite in this slice is of irregular shape; a few crystals only are twinned.

If we except the minute crystals just described, and those caught up in augite, the felspar crystals seen in this slice are as a rule well shaped, though many, even of these, are frayed out at one end; that is to say, they have thrown out one or more long and slender terminal prisms indicating that their crystallization, though deliberate at first, was ultimately brought to a sudden and rapid termination.

Here and there the felspar exhibits the multiple twinning of triclinic felspar; a few sanidine prisms exhibit single twinning; but in most of the crystals all trace of twinning is absent. The substance of the prisms has been much invaded by greenish granular matter similar to that seen in the base, and it is difficult to say whether it was caught up in the act of crystallization or whether it is the result of subsequent alteration.

The slice contains no magnetite, and some of the felspar is sanidine. There are a few fields of viridite in the slice.

No. 4.—A greenish-grey compact rock weathering to a light brown colour. Sp. G. 2·84.

M.—This slice exhibits the usual arrangement of felspar and augite scattered about in a devitrified glassy base. Some of the felspar is seen to be triclinic, but in the majority of cases, owing to kaolinisation, the twinning is no longer to be traced. I think, however, from a consideration of the azimuth at which extinction occurs, that some of the felspars are probably sanidine.

This slice contains numerous instances of the enclosure of the glassy base by felspar in the act of crystallization, similar to those already described. An illustration of one of these is given at fig. 10. In some instances these enclosures run the whole length of the prism and maintain a uniform thickness throughout. Another illustration of one of these enclosures is given at fig. 12, plate II.[1] In this case the magma enclosed has thinned away towards the centre of the prism, being thick at both ends. It is not a case of two prisms in close conjunction as one might suppose from the illustration, but of one prism with the glassy base caught up in it.

The augite in this rock is much altered. The slice contains several cracks, filled with quartz, which die out within the slice itself—cracks formed I presume on cooling.

No. 5.—A greenish-grey compact rock, brown and rotten at the edges. Sp. G. 2·69.

This rock occurs on the margin of the outcrop where the trap first appears.

M.—The whole ground mass has been converted into viridite in which the felspar crystals are starred about.

Here and there the triclinic character of the latter can be made out, but their internal structure has been a good deal altered into granular matter. Scattered through the slice are granules of a dichroic yellowish mineral which appears to be epidote. Its shape is irregular and its internal structure is micro-granular. No augite is visible.

[1] This crystal somewhat resembles one of the crystallites in pearlite depicted at fig. 20, plate I, Zirkel's Microscopic Petrology of the 40th parallel.

Descent from Dhalog to Sandára on the Ravi.

No. 6.—A greenish-grey compact rock weathering brown. Sp. G. 2·80. The rock occurs where the trap first crops out.

M.—One of the first objects that strikes one on looking at this slice is the abundance of the light brown glassy base which is partially devitrified into fine grained granular matter. In this base crystals of felspar and augite are scattered about. Very little magnetite or ilmenite is to be seen, but there is much leucoxene, the product of the decomposition of the latter.

Much of the felspar is seen to be triclinic, but some of it is sanidine, and probably both are equally abundant. The felspar is considerably decomposed by the invasion of viridite, and part of it is coloured red by the presence of fine granular matter in it which is too minute to be determined.

Augite is abundant in irregular shaped prisms, and much of it is twinned. It is not in a fresh condition, but its alteration is not in an advanced stage.

Water has percolated freely through the rock, and meandering lake-like spaces, plugged with scolecite and viridite, are to be seen here and there. Flakes of mica are scattered through the viridite.

The penetration of augite by felspar prisms, which are more attenuated in the middle of the augite than towards the margin of the latter, similar to those previously described, is very frequent.

No. 7.—A greenish-grey compact rock, somewhat mottled in appearance. Sp. G. 2·84.

M.—This slice in its general aspect very closely resembles No. 3, except that the felspar prisms and augite crystals are better formed and are of more regular shape.

The felspar is almost completely kaolinised, and all trace of twinning has consequently been obliterated. Nearly all the augite is partially altered. No unchanged magnetite is discernible in this slice or in No. 3. A portion of this slice is depicted at fig. 3, plate I.

No. 8.—A greenish-grey compact rock with streaks of epidote in it. Sp. G. 2·87.

M.—Epidote, associated with quartz, forms large veins running through the rock and takes up the greater part of the slice; whilst smaller veins of epidote alone, and of quartz alone, traverse it in other directions. The general mass is likewise much penetrated by epidote. The epidote is in a minutely granular condition, though well shaped microscopic crystals are to be seen in abundance along the edges of veins.

The rock itself consists of the usual felspar crystals starred about in a devitrified glassy base. All the felspar crystals are greatly altered and invaded by granular matter. No unaltered augite remains, and nothing distinctly recognisable as augite. Rod-like and dendritic forms of magnetite are abundant in the base.

No. 9.—A greenish-grey compact rock. Sp. G. 2·76.

M.—Augite is abundant and is in rather massive, irregular shaped prisms. The slice contains, however, one long slim augite. Twinning is not common. All the augite is more or less browned as the result of partial alteration.

The felspar is in well-shaped prisms of moderately large size. It is much kaolinised, and the twinning can only be made out here and there. The slice apparently contains both plagioclase and sanidine.

Amygdules of viridite (delessite ?) and scolecite are prominent, and flakes of mica are to be seen in both. All the ilmenite has been converted into leucoxene.

Trap from the Ravi section between Simliu and Kairi.

No. 10.—A mottled greenish-grey compact rock. Sp. G. 2·78.

M.—Augite is abundant in this slice, but it is all more or less altered and converted here and there into a serpentinous product.

The felspar is greatly kaolinised. A serpentinous variety of viridite is abundant and contains some crystals of epidote.

Here and there the original glassy base, now partially devitrified, is still to be made out.

No. 11.—A mottled greenish-grey compact rock. Sp. G. 2·86.

M.—This slice is very similar to the last, but the augite is still more altered. An irregular vein filled with epidote meanders through the slice. The triclinic character of some of the felspar can still be discerned, but the rest is completely kaolinised.

No. 12.—A pale greenish-grey, perfectly compact rock with a vitreous aspect. Sp. G. 2·84.

M.—The slice consists of a devitrified glassy base in which numerous crystallites of felspar are starred about. The base is composed of micro-granular matter of grey colour with a faint greenish tinge in it. Diffused through this are patches of minutely granular matter, of irregular outline, that polarises between crossed nicols. It is probably imperfectly formed epidote and may possibly represent pre-existing augite.

The slice is traversed by numerous veins filled with crypto-crystalline and apparently felspathic material crowded with countless, colourless, hair-like microliths. These veins were apparently filled by an exfiltration process during the cooling of the rock.

Below the Staging Bungalow Mámul to the west.

No. 13.—A mottled compact rock varying from green to purple. Sp. G. 2·73. B.B : fuses to a black magnetic bead.

M.—This slice consists of a glass, partially devitrified and exhibiting flow structure, containing a large amount of ferruginous, minutely granular material, arranged in flocculent masses. Much of it is peroxidised, and this imparts a red appearance to the slice in reflected light. In this base are scattered minute and irregular shaped prisms of felspar which exhibit no twinning. A comparatively large one has the multiple twinning of a triclinic felspar. Here and there patches of leucoxene are to be seen, but no augite.

The slice contains a few shapeless grains of a dichroic and minutely granular mineral ich appears to be epidote.

No. 14.—A greenish-grey compact rock. Sp. G. 2·86. B.B : fuses easily to a dark bead.

M.—This slice consists of a devitrified glassy base in which imperfectly formed crystals of felspar are scattered about. It very much resembles No. 12.

Conclusion.

All the above specimens give abundant evidence of having been lavas erupted at the surface of the earth's crust. No existing volcano could yield a more typical lava than No. 4.

The Dalhousie traps appear, on the whole, to belong to the basic type. No. 5 may possibly belong to the intermediate series, but No. 13 was evidently a highly glassy rock, approximating to a basalt glass, and No. 5 may have belonged to this class also.

Augite is abundant in all the other specimens except in Nos. 12 and 14 (in which it is wanting); and their specific gravity ranges from 2·76 to 2·87; their average being 2·83. The specific gravity of Nos. 12 and 14 is 2·84 and 2·86. All the specimens described in this paper, except No. 5, clearly belong to the basic class.

Sanidine is present in most of the specimens, but it plays a subordinate part. The presence of a small amount of sanidine, even in true basalts, is not specially remarkable.[1]

Considering the extent to which alteration has proceeded, the absence of olivine was only to be expected, for it is one of the first of the basaltic minerals to decay, and it may have furnished the materials for the formation of some of the secondary minerals so abundant in these rocks. On the whole, I think, the Dalhousie traps may be classed as altered basalts.

The next question which arises is whether the microscopical examination of these rocks throws any light upon their geological age.

The idea that basalts are tertiary rocks has long since been exploded, and it is now known that they may be of any age. Moreover, those who formerly held that basalts are of tertiary age would probably have classed the rocks now described as melaphyres. I discard the name melaphyre myself, because its use is apt to be misleading, inasmuch as altered plutonic rocks are sometimes included under that term.

All the specimens examined show that the Dalhousie traps are greatly altered. In none is the augite fresh; whilst in some it is altered almost past recognition.

The felspar is, as a rule, more or less kaolinised; whilst throughout the slices secondary products are abundant.

The extent to which alteration has proceeded in these rocks is in my opinion a good argument in favour of their being of considerable geological age.

The alteration exhibited appears, from the aspect of the rocks under the microscope, to have been the result of either the slow percolation of water or of hydro-thermal agencies. This alteration is not a mere local peculiarity, but appears to prevail throughout these rocks and to extend over a large area.

Considerable time must surely have been required for the production of the uniform changes to be seen in these dense traps. In the absence of evidence to

[1] See Zirkel's Microscopic Petrology of the 40th Parallel, pp. 216-229.

Fig. 1×30

Fig. 2×30

Fig. 3×30

... from the original drawings at the Surveyor General's Office, Calcutta.
October, 1883.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

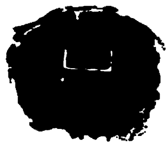

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Fig. 11

Fig. 12

Reproduced in heliogravure from the original drawings at the Surveyor General's Office, Calcutta.
November 1883

the contrary, I think we may safely conclude that the extent of alteration affords, in a rough way, a measure of the age of these rocks.

The basalts of Bombay are believed to be of upper cretaceous or lower tertiary age ; and if we compare the extent to which alteration has proceeded in the two rocks,—both being basic lavas of much the same character—I think it is logical to infer, unless and until evidence to prove the contrary can be adduced, that the traps of the Dalhousie area are considerably older than the basalts of Bombay. The result of their examination under the microscope is therefore to support the conclusion, as to the age of the traps described in this paper, arrived at on other grounds in my paper on the geology of Dalhousie.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Altered basalt. Dalhousie. Slice No. 3. Sketch intended to give a general idea of the way the augite and felspar crystals are interlaced and grouped together in clusters.

Fig. 2. Another portion of the same slice showing the feathery terminations of some of the felspar crystals and the intergrowth of augite and felspar consequent on the simultaneous crystallization of these minerals.

Fig. 3. Altered basalt. Dalhousie. Slice No. 7. Crystals of felspar and augite are seen scattered about in a partially devitrified glassy base.

PLATE II.

Fig. 1. An incomplete or skeleton form of felspar crystal. Slice No. 3. The result of rapid solidification.

Fig. 2. Intergrowth of augite and felspar, the result of rapid cooling. Slice No. 3.

Fig. 3. Another skeleton form of felspar crystal. Slice No. 3.

Fig. 4. Ditto.

Fig. 5. Ditto.

Fig. 6. Ditto.

Fig. 7. Skeleton crystal of felspar which has, owing to rapid cooling, enclosed a portion of the base. Slice No. 3.

Fig. 8. Intergrowth of augite and felspar. Slice No. 3.

Fig. 9. Ditto.

Fig. 10. Enclosure of the base by a skeleton crystal of felspar. Slice No. 4.

Fig. 11. Intergrowth of augite and felspar. Slice No. 3.

Fig. 12. Enclosure of glassy base by skeleton crystal of felspar. Slice No. 4.

On the microscopic structure *of some* sub-Himalayan rocks *of tertiary age, by* COLONEL C. A. MCMAHON, F.G.S.

No. 1.—A fine-grained sandstone of the Sirmur series, containing a fossil leaf, found by Mr. Medlicott south-east of Chune, on the Ravi. The following note on this specimen is taken from the Records of the Survey of India, Vol. IX, p. 52:—"In this very crushed, probably inverted, outcrop I found a characteristic sample of the Kasauli plant bed, the only occurrence of it known west of the Sutlej."

M.—The grains of quartz in this slice are nearly all angular, and only a few here and there are subangular.

Grains of granular limestone are numerous, and one fragment of felspar is present. Leaves of biotite (?) and muscovite are to be seen here and there, and are evidently original constituents of the rock and were deposited along with the sand. The leaves of mica are bent round and conform to the external shape of the grains between which they are jammed. The sand of our Panjab rivers is full of fragments of mica.

The slice contains some green dichroic grains that may have resulted from the degradation of trap. It also contains fragments of garnet and of schorl.

The interstitial mud has been converted into a crypto-crystalline material.

I have only detected liquid cavities, with movable bubbles, in one grain of quartz. The bubbles are extremely small ones.

Specimens of fine-grained sandstones from Bhond.[1]

No. 2.—This specimen closely resembles the last described. It contains fragments of schorl, muscovite, and green mica. Grains of calcite are present, but they are not so abundant as in the last. There are some micro-garnets and a little hæmatite. I have observed no liquid cavities in the quartz.

No. 3.—The same as the last. The slice contains four minute fragments of plagioclase. Calcite is sparce, and the quartz contains no liquid cavities with bubbles.

No. 4.—This specimen is very similar to the preceding ones. It contains more calcite than the last and more argillaceous material. It contains neither schorl nor garnet, but liquid cavities with movable bubbles are present in the quartz.

No. 5.—The grains of quartz are in angular fragments closely dovetailed together. The interstitial mud which occurs in patches is dark between crossed nicols showing doubly refracting fibres scattered about in it, apparently of felspathic material.

The slice contains some grains of schorl and fragments of green mica and muscovite. Some of the grains of quartz contain liquid cavities with movable bubbles.

In this, and one of the previous slices, a quartz grain contains a microlith with an internal shrinkage cavity,—a circumstance that indicates an igneous

[1] Records XVI, p. 35.

origin and shows that the grain of quartz was derived from the waste of granite or similar rock.

No. 6.—This slice consists of fragments of quartz and a muddy cement converted into a crypto-crystalline material; it contains fragments of schorl, muscovite, green mica, calcite, and one of garnet. There are patches of chloritic material here and there.

Some of the quartz grains contain liquid cavities with movable bubbles.

Red clays—Bhond.

No. 7.—This consists of angular pieces of quartz and fine fragments of muscovite imbedded in very fine red mud. Patches of hæmatite are present here and there.

No. 8.—Much the same as the last specimen. There is less mud and more fine-grained siliceous material and more white and green mica. The slice is of somewhat variegated colour owing to the presence of dark and clear irregularly defined bands.

In one of the quartz grains I detected liquid cavities with small movable bubbles.

No. 9.—Much the same as No. 7. Muscovite is more sparse, and I have not detected any liquid cavities in it.

Kasauli sandstones.

No. 10.—This slice consists of angular fragments of quartz and patches of consolidated mud; it contains pieces of schorl, leaves of silvery and of a yellowish-green mica; also a piece of triclinic felspar; a few small garnets and a fragment of a larger one.

Some of the quartz grains contain movable bubbles, but they are small and sparce. One grain of quartz contains a microlith of hornblende, in which are numerous grains of opacite and several enclosures with fixed bubbles in them. Another quartz grain is full of transparent hair-like belonites. This specimen contains no calcite.

No. 11.—This slice greatly resembles the last. It contains muscovite, a reddish-brown mica, schorl, numerous large pieces of garnet, a little granular calcite, a fragment of epidote and fragments of a carbonaceous slaty rock. The muscovite is in good-sized leaves.

Some of the grains of quartz exhibit a polysynthetic structure, whilst others contain microliths of muscovite similar to those so characteristic of the gneissose granite of the North-West Himalayas. There are some fragments of crypto-crystalline mica (another characteristic of the gneissose granite) and a grain of fibrous felspar (a form of microcline,—see Records XVI, 131).

There is a small fragment of triclinic felspar and, I think, of decomposed orthoclase.

Some of the quartz contains liquid cavities with movable bubbles.

Bakloh sandstones.

Nos. 12 and 13.—These slices consist of angular and sub-angular grains of quartz set in mud. The quartz is not very clear or pellucid, being here and there.

milky and opaque; and some of the grains exhibit a polysynthetic structure. The earthy portion is stained yellow with oxide of iron, and here and there brown dots appear which are probably limonite.

No calcite or mica is present, but there are a few small fragments of a dichroic mineral that may be schorl.

No. 12 contains cavities with bubbles, but not movable ones.

No. 14.—This rock so closely resembles the Kasauli sandstone that a separate description is unnecessary. Schorl, a small garnet, and a little felspar are present in the slice. The quartz contains liquid cavities with movable bubbles and stone cavities with fixed bubbles and mineral deposits. Muscovite is sparce.

Dagshái sandstones.

The specimens described below were taken from the side of the Simla cart road facing Dagshái.

Nos. 15, 16, and 17.—These are seen under the microscope to be composed of fragments of quartz and of slaty rocks, some of which appear to be carbonaceous. Fragments of well crystallised calcite and of schorl are also present. Each slice contains a few pieces of triclinic felspar, one of which includes microliths of muscovite. Leaves of muscovite and a yellowish-green mica are abundant.

One of the grains of quartz has crypto-crystalline mica attached to and penetrating it. It has all the appearance of being a fragment of the gneissose granite. There are also separate fragments of the crypto-crystalline mica. Some of the quartz grains are polysynthetic.

A few small garnets are present, and liquid cavities with movable bubbles are abundant in the quartz.

Siwalik series (Nahan beds ?), Naini Tál road.

Nos. 18, 19, and 20.—These consist of angular pieces of quartz, bits of slate, and a little mud, the quartz predominating. Leaves of muscovite and a greenish mica and fragments of schorl are present in the slice. Some of the quartz grains contain microliths of muscovite similar to those contained in the gneissose granite. Some of the quartz is milky and opaque, and none of it is particularly hyaline.

Liquid cavities are numerous in the quartz, but those with bubbles are comparatively sparce.

Nahan sandstone—Nalagarh.

No. 21.—This slice consists of angular and sub-angular grains of quartz, quartzite, slate, limestone, schistose rocks, and kaolinised felspar, cemented together with mud. Some of the slate appears to be carbonaceous.

A good many of the grains of quartz are of polysynthetic structure similar to the fish-roe grains of the gneissose granite. The slice contains a fragment of triclinic felspar and a few of the foliated variety of microcline. Much of the quartz is milky and opaque; muscovite is present and also a few fragments of schorl.

Liquid cavities with movable bubbles are numerous in the quartz; also air cavities.

Nahan sandstone—Mailog.

Nos. 22 and 23.—These specimens are composed of angular grains of quartz imbedded in fine mud of greenish colour. The slices contain fragments of schorl and the quartz liquid cavities with movable bubbles.

Siwalik (?) sandstone. Dhár.

The undoubtedly Siwalik sandstone of the outermost range is too friable to admit of slicing, but except in induration it seems lithologically identical with the Dhar rock.

No. 24.—This slice very much resembles No. 21 in its general appearance under the microscope and in the nature of its contents. Both contain fragments of red quartzite, green schists containing magnetite that remind me much of hornblendic beds near Shiel, in the Jubal State, beyond Simla; and fragments of a rock that looks like a decomposed amygdaloid. No. 24 differs from No. 21 in containing fragments of a pink garnet, flesh-coloured in transmitted light. Muscovite is present in large leaves in No. 21, but in No. 24 no mica is present, except in the form of microliths in the quartz. No. 24, moreover, does not contain any "fish-roe" quartz.

Both rocks under the microscope are generally so similar, that if they do not represent the same beds, at any rate, some of the rocks that were exposed and in process of erosion when the Nalagarh beds were laid down must have been in process of erosion when the Dhar beds were deposited.

The slice under description (24) contains a doubly refracting mineral that appears to be schorl.

The garnets are full of air cavities; whilst liquid cavities with large movable bubbles are abundant in the quartz.

Conclusion.

A microscopic examination of the fine-grained earthy sandstone containing a a fossil leaf found by Mr. Medlicott in the Sirmur horizon on the Ravi, and of the beds trans-Ravi at Bhond, and of some of the beds under Bakloh (in which fossil leaves have also been found); and a comparison of these rocks with a thin slice of a typical Kasauli bed leave no doubt in my mind that the Kasauli leaf beds continue into the Dalhousie area.[1] Their position, in the Dalhousie region, appears to be near, but not on, the northern boundary of the outcrop of the Sirmur series.

The Kasauli leaf beds, in which name I include all those alluded to in the last paragraph, are composed of very fine-grained angular fragments of quartz, grains of calcite or granular limestone, fragments of carbonaceous slaty rocks, and consolidated mud. Leaves of muscovite and of a greenish mica—evidently original constituents of deposition—are squeezed between the grains of quartz;

[1] I have some very perfect fossil leaves imbedded in an exactly similar rock found by Mr. C. J. Rodgers at Dharmsala and given me by that gentleman.

whilst either minutely triturated fragments of mica are mixed up with the mud, or a portion of the latter has been converted into that mineral. The former explanation seems the more probable one.

Taking the specimens of the Sirmur series described in the preceding pages as a whole, they appear to have had their origin in the subaerial waste of the carbo-triassic limestones, infra-carboniferous slates, granitic rocks, and probably to a small extent of traps. The evidence afforded by the Sirmur sandstones on the latter point, however, is feeble.

A prominent feature in most of the slices is well crystallized or granular limestone, in fragments that have all the appearance of having been deposited with the other constituents of the rock. They are all isolated fragments; there are no veins or connecting links between them, and nothing to support the supposition that they have been formed by an epigenital process after the consolidation of the sandstone. I can only regard these as fragments of limestones, and I think the inference a natural one that the carbo-triassic series was exposed at the surface and was suffering denudation when these tertiary sandstones were formed. We know on other evidence that in the Simla area these limestones were deeply eroded by subaerial agencies[1] in pre-tertiary times.

The presence in these sandstones of fragments of carbonaceous slaty rocks that would answer well for the infra-Krol series also supports this view.

But infra-Krol and Krol rocks were evidently not the only ones that were suffering denudation in the Himalayan area when the Sirmur series were laid down. The presence of schorl, of a type characteristic of granitic rocks; of fragments of garnet, a mineral very abundant in such rocks in the North-West Himalayas; of muscovite and a dark green mica; of triclinic felspar, and of the fibrous variety of microcline, taken in connection with the character of the quartz grains, indicates, I think, clearly enough, that granitic rocks were also exposed at the surface and were suffering denudation when the sandstones were formed.

The schorl and muscovite I should say undoubtedly came from granitic rocks; the former is of the type characteristic of such rocks, and does not resemble the tourmaline found in the silurian sandstones of the Dalhousie area.

Garnets might of course be derived from a variety of rocks, but at the same time it must not be forgotten that this mineral is abundantly present in the granites and gneissose granites of the Himalayas.

But the character of the quartz is the most important point in connection with the subject under consideration. Liquid cavities with movable bubbles are abundant in many grains; in quite as large a proportion of grains as one could reasonably expect on the supposition that they were derived from Himalayan granitic rocks. Then we have grains containing microliths with shrinkage cavities in them, exactly similar to those found in our Himalayan granites; and in No. 10 we have a hornblende microlith containing several enclosures with fixed bubbles in them; whilst in No. 14 we find quartz grains containing stone cavities with fixed bubbles, and mineral matter either deposited by the mineral material of the "stone enclosure" on cooling, or caught up by it in the act of consolidation. All the above are eminently characteristic of granitic

[1] Manual, pp. 533, 569.

rocks and could be matched, over and over again, in the granites and gneissose granites of the Himalayas.

Other points to be noted are that some of the quartz grains exhibit a polysynthetic structure, and that both quartz and felspar contain microliths of muscovite; whilst Nos. 15—17 contain fragments of crypto-crystalline mica, and a quartz grain penetrated by crypto-crystalline mica. The study of the granites and gneissose granites of Dalhousie and the Satlej valley, under the microscope, has shown that polysynthetic quartz, microliths of muscovite in quartz and felspar, and crypto-crystalline mica are very characteristic of these rocks.

On the whole, then, I cannot doubt that much of the material of the Sirmur sandstones were derived from the waste of granitic rocks.

The comparative paucity of felspar may I think be explained by the fact that this mineral is not so hard as quartz, schorl, or garnet, and consequently must have suffered more than these minerals from trituration. It is moreover very liable to decomposition, and doubtless it was the felspar that suffered most in the passage of granitic detritus down the Himalayan streams and rivers, and supplied a considerable proportion of the constituents of the mud that forms the binding material of the sandstones. The felspar suffered more than the limestones, because, I presume, it had to travel further, and came from the axial ridges of the Himalayas, whilst the limestones were nearer home.

Mica is soft, but is very indestructible; and its very lightness and buoyancy in water doubtless preserved it from injury by the way.

Another question remains, namely, were the granitic materials derived directly from granitic rocks, or were they first deposited in ancient clastic rocks and supplied to the Sirmur sandstones on the breaking up of those rocks?

I do not think the latter supposition a probable one. The schorl and garnets are very fresh, and had they lain for long geological periods in ancient clastic rocks before they found a resting place in the Sirmur sandstones, I think they would have shown considerable signs of alteration or have been transmuted into other minerals that result from their degradation.

Assuming then that the granitic materials were directly derived from granitic rocks, the important question arises, were they derived from rocks now visible or from some others?

It does not seem probable that any granitic rocks can have been exposed in the Sirmur sandstone age other than those now visible. It is conceivable that some old intrusive sheets may have been removed by erosion, but they must have left their roots behind in any case.

That rocks of very similar appearance to the gneissose granites described in a previous paper, and which I regarded as of tertiary age, must have been exposed in silurian times, is clear, for the upper-silurian conglomerate contains boulders of granitoid gneiss. Samples of these boulders have not as yet been subjected to a critical examination in the laboratory, and it would be premature to express any decided opinion regarding the character of this granitoid rock; but whatever it may turn out to be, there seems to be no reason why we should suppose that granitic intrusions into the Himalayan area took place during one period only, or that they were limited to the special Himalayan disturbances of post-eocene times.

If these eruptions began in pre-tertiary or early tertiary times, the fact tha gneissose granite had come to the surface and was suffering erosion when th Sirmur series were deposited presents no difficulty.

That the gneissose granite was already exposed when the Siwalik congle merates were laid down, does not admit of a reasonable doubt, for the congle merates are full of boulders of a rock undistinguishable from it; and the Siwali conglomerates afford internal evidence of being derived from local sources.

In my paper on the microscopic structure of the Dalhousie gneissose granit (*supra*, p. 143) I spoke of this rock as of probably tertiary age and said that i was probably "brought into its present position in the course of the throes tha gave birth to the Himalayas." Whilst I adhere to that statement, I desire to poin out that it is not necessary for us to assign a late period in the tertiary age fo the invasion of silurian beds by a hypogene rock of this character; or indeed t pin ourselves down to the tertiary period at all. The facts disclosed in thi paper would harmonise better with the supposition that the eruption of th gneissose granite took place at a somewhat earlier date than that usually assigne to the beginning of the last series of special Himalayan disturbances.

It has been shown in the Manual of the Geology of India (pp. 525, 569-570 that the disturbing action proceeded with great slowness; that the Himalaya river gorges in Siwalik times were the same as now; that the sea was probabl excluded from the sub-Himalayan region from early tertiary times; that eleva tion preceded compression; and "before any special contorting action had set in the general condition of sub-Himalayan deposition had been established by general (continental) elevation of the Himalayan area."

The Krol (carbo-triassic) rocks in the Simla area were deeply denuded b subaerial agencies (Manual, pp. 533-569) before the eocene nummulitics wer laid down, and the Sabathu beds are "very variable in thickness suggesting limit of deposition to the north-east." In other words, the Krol area in the Siml region was above water and formed dry land in pre-tertiary times; and if so, i seems only reasonable to suppose that the central axis of the Himalayas, if no throughout its whole length, had also, in part, at any rate, risen from the se and formed more or less elevated land in pre-tertiary times, and so we find it state in the Manual, page 571, that "a considerable Himalayan elevation occurred i pre-tertiary and early tertiary times."

The process of elevation doubtless was a slow and gradual one and extende over a lengthened period; but the "continental elevation" of the Himalaya area during a pre-tertiary period is just as likely to have been accompanied wit hypogene granitic invasion of deep-seated rocks below the surface, as the subse quent period of special disturbances which took place during the tertiary period

Whilst therefore I hold that the invasion of silurian rocks by gneissose gra nite was connected with the elevation and formation of the Himalayas, and thin it probable that, in the Dalhousie area, the eruption of the gneissose-granite too place at the close of the eocene, or early in the miocene period; at the sam time, I do not see that we need necessarily associate the eruption of all th gneissose granite of the North-West Himalayas, or indeed any of it, wit the latest phase of the special disturbances which began in post-eocene times.

Note on the Geology of Jaunsar *and the* Lower Himalayas, *by* R. D. OLDHAM, *Geological Survey of India.* (With a map.)

1. The last season's work in the Himalayas having shown that the series as adopted ever since the publication of Mr. Medlicott's Memoir on the Lower Himalayas [1] requires some modification and extension to make it applicable to portions of the Lower Himalayas lying outside of the Simla section, it has been thought advisable to publish a short note showing the results of the resumed survey as far as it has gone; but while confining myself as far as possible to what may be said to be definitely proved, it will be impossible to steer clear of other points still doubtful, and these, which I shall distinguish to the best of my ability, must be taken with every necessary reservation.

2. One of the chief difficulties when starting work in Jaunsar, a district chosen chiefly on account of the fact that large scale maps were obtainable, lay in the fact that, with the exception of a great limestone series reasonably identified with the Krol, no representative of any of the sub-divisions established on the Simla section was to be recognised.

3. The oldest formation here, which I shall provisionally call the Chakrata series, consists of grey slates and quartzites, underlaid by a band of limestone generally some 300 or 400 feet thick, which is again underlaid by a great series of slates and quartzites marked by the prevalence of red and mottled beds. The principal exposures of the limestone lie in a zone running about east and west, and passing immediately to the south of the station of Chakrata; to the north of this zone the hills are formed of the underlying red Chakrata slates and quartzites, while to the south the upper grey slates are exposed, notwithstanding the prevailing northerly dip of the beds. This is but part of the great Himalayan puzzle, that newer beds almost always seem to dip under older, that faults are generally reversed, and that the dip of the beds in their neighbourhood is precisely the reverse of what would be expected on *à priori* grounds. The total thickness of these beds is indeterminable, partly on account of their intense disturbance, and partly from the fact that neither their base nor summit has been seen, but it must amount to many thousands of feet.

4. In northern Jaunsar there is another exposure of the same beds intersected by a great fault which, first appearing from underneath the Deoban limestone near the village of Konain, runs north-westwards to Mudhaul, on the west of the Tons, and which I shall refer to as the Konain-Mudhaul fault.

5. To the east of this fault there is exposed a great thickness of grey slates and quartzites, over which comes a band of blue limestone 300 to 400 feet thick, and over this white and coloured quartzites with interbedded red and grey slates; and near Kanda, what appear to be contemporaneous, but may be intrusive, beds of trap, overlaid by greenish slates, which last are covered unconformably by the Deoban limestone. Among the quartzites there is, near Kanda, a band of coarse quartzite conglomerate about 8 feet in thickness, which has been marked

[1] Mem. G. S. I., Vol. III, pt. 2.

on the map illustrating Colonel McMahon's paper[1] as Blaini; but the associated beds and the absence of the characteristic limestone seem to render this impossible.

6. To the west of the fault the section as seen on the ascent from Anu[2] to Banu is first white quartzites with interbedded green and grey slates, overlaid by green and grey slates without quartzites and these again are capped at Chajar (Chilar) by a small patch of blue limestone, which can hardly be anything but the same that is exposed near Kanda, and which I correlate with the Chakrata bed. The only other thing it could well be is the Deoban, but though on the upthrow side of the Konain-Mudhaul fault so far as it affects the Deoban limestone, it is at a lower elevation than the base of the latter as exposed above Banu on the eastern or downthrow side.

7. Here, whether the limestone band be identified with the Chakrata bed or no, there seems to be an inversion on one side or other of the fault, probably to the east, and it is evident that the fault must have a throw sufficient to bring the same bed on either side of the fold to about the same level; it is at present impossible to say for certain which is the up and which is the down throw side, nor to determine even approximately, the throw of the fault, but it must certainly be measured by thousands of feet.

8. In several parts of Jaunsar volcanic beds are exposed in the Chakrata series; to the east of Chakrata, in the valleys of the Kutnu and Mord gadhs (stream), there are several beds of volcanic breccia and ash lying both above and below a thick band of blue limestone identifiable with great probability as the Chakrata band near Lauri the same limestone again crops out and is once more associated with the volcanic beds, which are also seen in the valley of the Gamgadh.

9. In the Tons below Anu there are exposures of a brown ferruginous and dolomitic limestone, passing into crystalline ankerite in places, which I have conjecturally correlated, notwithstanding its lithological difference, with the Chakrata limestone. The volcanic beds associated with it are here far more extensively developed than I have seen elsewhere in Jaunsar and I consider that the peculiar nature of the rock is due to a contemporaneous admixture of volcanic detritus a supposition which is supported by the facts that the southernmost of the exposures as it is traced eastwards becomes less and less ferruginous, till near its disappearance it is in parts a blue limestone little if at all more impure than the normal Chakrata limestone, and that on the western side of the Tons valley above Anu there is an exposure of presumably the same band which, while being in parts bluish-grey limestone, is also in parts extremely ferruginous. The facts just mentioned seem to point to a centre of volcanic energy shortly to the west or south west of the confluence of the Binalgadh with the Tons, while the volcanic beds of eastern Jaunsar were very possibly derived from a vent in what is now Tiri Garhwal.

[1] Rec. G. S., Vol. X., 204. [This outcrop was mapped by me, not by Colonel McMahon; I only crossed the ground once, when marching with Dr. Oldham from Mussooree to Simla 1860.—H. B. M.]

[2] Misprinted *Dnu* in the map.

10. This zone of volcanic beds promises to be a horizon of great value in tracing out the geology of the Lower Himalayas, and it may not be out of place to indicate the probability of their being contemporaneous with the silurian volcanic rocks of Kashmir and the North-West Himalayas. At the same time I must point out that it is not absolutely certain that they are of the same age as the Chakrata limestone; for although the limestone with which they are associated occurs in a similar position to, and is most probably the same as, the Chakrata bed, yet it must not be forgotten that in the typical area no associated volcanic beds were seen.

11. Overlying the Chakrata series comes a great thickness of limestones and dolomites so similar to the Krol series as to be almost certainly contemporaneous with it, but which, as its relation to the underlying beds is very different to what has been described on the Simla section, I shall provisionally call the Deoban limestone. Lithologically it consists of a great thickness of bluish-grey bedded limestones, some of the beds, as on the ascent to Deoban from Chakrata, containing many nodules of chert; others which are generally mephitic have a peculiar pisolitic structure, being composed of small round black nodules cemented by a white calcareous matrix: a peculiar structure seen in some of the beds makes them resemble an accumulation of some closely-chambered shells imbedded in a matrix of calcareous mud, and so organic looking that it is difficult to believe that they are not obscured fossils. A very considerable proportion of the beds is in some of the sections dolomitic, varying from a slightly magnesian limestone to a pure pale-grey crystalline dolomite. Interstratified with these calcareous beds is a varying proportion of slaty beds, occasionally coloured, but as a rule grey.

12. This series is quite unconformable to the underlying Chakrata beds, as is proved by its unconformably overlapping or overstepping their eroded edges. This is very well seen near Konain, where the Deoban lies on the Chakrata limestone while as the boundary is traced to the west it is seen to rest successively on a (locally) descending series of slates; the unconformity is further indicated by the way in which the limestone rests, above Kanda, on the eroded edges of the presumably inverted Chakratas, and by the fact that the Konain-Mudhaul fault which, as above explained, has a throw of some thousands of feet in the older rocks, has, where it cuts the Deoban limestone, a throw of a few hundreds at most, this being due to a later movement along the original fracture; it would serve no useful purpose to describe every junction of the two series, as the same facts are everywhere to be seen.

13. It is evident that this is very different to what has been described on the Simla section,[1] and there are but three possible explanations—1*st*, that the Deoban and Krol limestones are not contemporaneous; 2*nd*, that the junction on the Simla section is only apparently and locally conformable; 3*rd*, that the Chakrata series is older than the Simla slates and underlies them unconformably. The first supposition may, I think, be dismissed; the second I regard as very probable, the very sudden variations in the thickness of the Krol quartzite pointing to a

[1] H. B. Medlicott: Mem. G. S. I., Vol. III., *passim*, and Manual, pp. 594-609.

possible unconformity between it and the Krol limestone; the third is also p sible: but if the volcanic beds of Jaunsar are really of upper-silurian age, there hardly room for the whole of the sequence between these upper-silurians and t (at latest) triassic Krol limestone. At present sufficient facts are not at m disposal to enable me to say which of the latter two hypotheses may prove correc but the question depends very much on the nature and amount of the disturb ance of the Chakratas anterior to the deposition of the Deoban limestone. Th inversion at Kanda may have been a purely local feature, the Chakratas havin been elsewhere comparatively undisturbed at the time of deposition of th Deobans—in that case the second supposition may be correct, and the Chakrat beds either representatives of, or forming part of a conformable sequence in, th rocks below the Krol: but if it should ultimately prove to be merely part of widespread disturbance, the third hypothesis alone remains possible.

14. Above the Deoban limestone comes a series of beds mostly conglomerati first identified by me in the neighbourhood of the Mandhali forest bungalow after which I propose to call them, at any rate provisionally. They consist o conglomerates mostly with a slaty matrix through which pebbles of quartzit slate or limestone are scattered, though some and in southern Jaunsar th majority of the beds are not conglomeratic at all, others are coloured slates no unlike indurated Sirmurs, and others again are calcareous; of the latter, some ar fine-grained limestones, others, though this I have only seen near to Mandhali, ar limestone conglomerates cemented by a limestone matrix. The presence of the pebbles derived from the underlying Deoban limestone is sufficient to stamp th beds containing them as unconformable to it. In southern Jaunsar, in additio to the limestone conglomerate with slaty matrix, which is not found in ever exposure, the characteristic rock is a quartz grit containing fragments of indu ated red slate derived from the lower Chakrata beds.

15. The facies of the Mandhalis is essentially littoral, or shallow water, as i testified to by their coarseness of grain, while the conglomerates with a sla matrix, so similar to those of Blaini age, could not have been formed except throug the agency of floating ice; but it is not a little remarkable that, notwithstandin their evidently shallow water origin, there is hardly an exposure which does n exhibit one or more beds of pure limestone: this association of littoral beds wit limestone is well seen on the cart road to the north of Kalsi; where a thick ban of limestone is bounded on both sides by coarse-grained quartz grits.

16. Outside of Jaunsar I have detected these same beds, to the east in great forc near Naini Tal and Bhim Tal, and to the west, in the Giri valley, I saw in 188 some conglomerates, which at the time puzzled me not a little, but which I canno now hesitate to refer to Mandhali age.

17. As regards the homotaxy of the Mandhalis, they are later than the Deoba and are evidently of earlier date than the main disturbance of the Himalaya rocks; so much so that in the limestone area of northern Jaunsar, the sma patches that have been left owe their preservation entirely to having been caugh up in the folds and faultings of the limestone, and in this way preserved fro denudation. They consequently occupy a position analogous to that of th Sirmurs to the northwest, and at first one would be inclined to correlate the

with the last-named rocks and assign to them an early tertiary age. However, the fact that nummulitics of normal type are to be found near Rikhi Khes in Garhwal[1] taken in conjunction with the extent of the Mandhalis, is against this supposition, which, too, it is impossible to reconcile with the finding of characteristic Mandhalis in the Giri valley, within a few miles of the boundary of the Sirmurs, in which no similar rock is to be seen. They must therefore be of pre-tertiary age, for there is no room in the sequence for them to come after the Sirmurs.

18. Above the Mandhalis are two series of rocks, of which, as they occupy totally distinct areas, it is impossible to say which is the older. Of these one is the Nahan; but as it occupies a very small area in the extreme south of Jaunsar, and as it presents no peculiarities, it may be dismissed without further notice.

19. The other series merits attention, as it presents an unsolved and apparently unsolveable problem. In north-eastern Jaunsar, occupying a considerable tract of country is a series of fine-grained glassy quartzites with interbedded schists, some of the beds containing granules of blue quartz, which in the Tons descend to the level of the river, but southwards merely cap the ridges; they lie almost undisturbed and nearly horizontal on the eroded edges of the intensely disturbed older rocks, and are evidently far newer than any of the other formations in Northern Jaunsar, or Bawar as it is locally called; yet, though so much newer and so much less disturbed, the rocks are far more metamorphosed than those of the older series, the siliceous beds being everywhere converted into glassy quartzites, and the argillaceous bands being, in Bawar, uniformly schistose, while across the Tons, in Garhwal, they occasionally become almost gneissose. I propose to call this the Bawar series.

20. As the Bawars are evidently of much later date than the main disturbance of the rocks, which in the Simla section has been shown to be of post-eocene date, they would seem to be referable to a middle or upper tertiary age; but it is difficult to suppose that rocks so metamorphosed can be contemporaneous with the soft sandstones of the lower or the loose shingles of the upper Siwaliks, and besides there are very strong reasons for believing that even in Nahan times the Himalayas existed as an elevated tract subject to denudation; nor is there any similarity between the Bawar and Nahan rocks even where the latter have been metamorphosed by igneous intrusions. It is however possible that these Bawars may be of lacustrine origin and contemporaneous with the Nahans,—a supposition supported to some extent by the extremely small development of the Nahans at the debouchure of the Tons and Jamna rivers, and by the fact that the Bawars so fine grained to the south of the Tons become near their summit, in Garhwal, coarsely conglomeratic. When more information has been collected, these difficulties may doubtless be cleared up, but the improbability of ever finding any fossils in these rocks is a serious hindrance.

21. The glacial epoch has left its traces in Jaunsar, though I know of no traces of actual glaciers to the east of the Tons. Above Kistur there are what might at first sight be taken for terminal moraines, but a more detailed examination

[1] Mem. G. S. I., III, pt. 2. p. 90; and Manual, p. 535.

banishes the idea; the only deposits that can be referred to this epoch are high-level gravels to be seen in most of the valleys but most distinctly in of the Seligadh where, as can be seen from the Chakrata and Mussoorie r they form broad gently-sloping terraces on the valley sides; the slope of surface is more rapid than that of the present bed of the stream, being 800 feet above the latter at Makhata while near the junction with the Ju the difference in level does not exceed 100 feet; in the small lateral val the slope rapidly increases, so that sometimes the gravel deposits run almost u the crest of the water-shed. These gravels have been formed since the Seli va was cut down to its present depth, as is shown by their extending in places r down to the present level of the stream; they could not have been formed u existing circumstances, for apart from the angularity of the fragments of w they are composed and the slope of their surface the peculiar parabaloidal c of the surface up the lateral valleys is totally different to what is now b formed anywhere in the lower-Himalayas, but could only have originated w the balance of disintegration and precipitation was very different to what is the case; disintegration must then have been so rapid that the streams could dispose of the debris which was shed from the hill slopes, the valley was co quently filled by a deposit whose surface had a comparatively gentle slope in main valley where the volume of the stream was greater, while in the la valleys, where the amount of debris was comparatively greater, the slop creased till it reached the angle of repose. It is needless to expatiate on fact that this increased disintegration can under the circumstances onl attributed to a more rigorous climate, frost being the great disintegrator in latitudes.

Notes on a Traverse through the Eastern Khasia, Jaintia, *and* North Cachar *by* Tom. D. LaTouche, B.A., *Geological Survey of India.*

The object of my season's work was to search for coal and iron within r of the proposed line of railway from Silchar to the Brahmaputra valley thr the North Cachar hills. From what was already known of the ground (I G. S., Vol. IV., pt. 3, 1865) there seemed to be little or no prospect of suc and so it has turned out.

Arriving at Cherra Poonjee about the middle of December, I spent a few in examining the area mapped by Mr. Medlicott in 1871 (Mem. G. S., Vol. V p. 151) so as to familiarise myself with the rocks in it. I then marched a the Jaintia hills to the North Cachar hills, visiting the coal-field of Laka on the way.

1. Lailangkot to Jawai.—Leaving the village of Lailangkot, which is sitt on the boundary of the Shillong series and the granite area of Molim, by the road to Jawai, Shillong quartzites and granite are passed over alternately fo first 5 miles, there being three exposures of granite extending across the to the south-west, and probably connected with the main area to the north. quartzites are vertical, or dip at very high angles with a general strike

Oldham:

77 45
55
50
45
40
35
30
30
77 45
J U B B A L
Sangota Br.
2210
S I R M U R
Kota

north-east to south-west. The last exposure of granite is about 1 mile to the south-west of Rableng hill. This hill consists of Shillong rocks, which extend without a break to the Mantedu at Jawai, the strike being generally between north and north-east but bending round to east-north-east between the Mangat (the boundary of the Jaintia hills) and the Mantedu. In this direction also the rocks become more schistose, several beds of fine-grained hornblende schist occurring in the valley of the Umthungpha, about 1 mile above its junction with the Mantedu. At the top of the hill to the east of the Mangat, near the village of Simunting, is a small outlier of cretaceous rocks.

Beneath the village of Jawai the schists and quartzites are capped by patches of cretaceous conglomerates, forming low hills in and about the villages; the bedding in these is horizontal.

2. *Jawai to Lakadong.*—Turning south from Jawai along the Jaintiapur road, Shillong rocks extend to the summit of the hill south of the Mantedu, where they are capped by fine cretaceous sandstones forming low scarped hills on either side of the road. Near the 5th milestone from Jawai the border of a small area of granite is passed on the right-hand side of the road, extending to the south-west. The road then runs round the south flank of a hill of cretaceous sandstones to the Mankajai, in the valley of which a broad dyke of trap occurs. This is a coarsely crystalline, dark-coloured rock with a rather metallic lustre and weathering red, and is entirely composed of augite and titaniferous iron. Cretaceous sandstone again appears in the scarp to the south of this valley, coarse at the base and becoming finer towards the top. These rocks continue to and beyond Jarain, forming an undulating plateau with slight inclination to the south.

Coal at Jarain.

At Jarain coal occurs in these rocks, and has been worked to a small extent to supply the dâk bungalows here and at Jawai. A seam crops out on both sides of a gully close to a small bridge on the road to the south-east of the village, and is about 3 feet thick, overlaid by about 12 feet of hard, fine-grained sandstone. It has the usual characteristics of the cretaceous coal of these hills. Another outcrop occurs at about $1\frac{1}{2}$ miles to the north-east of the village and 1 mile from the road, in a small stream running into the Um Pliang, a tributary of the Mantedu. The seam is well exposed, the stream flowing over it in a low fall. It is 3 feet 6 inches thick, with fine-grained sandstone above and below. This coal contains a good deal of pyrites in small nests, and at the base of the seam the rock is covered with a net-work of this mineral, so that the coal would be of very little value.

Turning off to the south-east from the Jaintiapur road in the direction of Lakadong, the path passes by Amlittshor village over the plateau of cretaceous rocks deeply indented on either side by tributaries of the Mantedu until the gorge of this river is reached. This gorge is here about 1,000 feet deep.[1] The cretaceous rocks extend on both sides of the gorge to about 300 feet from the top

[1] Unfortunately my aneroid was out of order, so that I was unable to measure exactly the depth of the gorges crossed in this part of the hills.

and rest directly upon metamorphic rocks, which extend on both sides to the bottom. These rocks are similar to the metamorphics found on the north slope of the hills.

From the top on the opposite side an undulating plateau of cretaceous rocks extends for about 4 miles to the village of Shushen, which is situated on the edge of the gorge of the Lauriang, about 3 miles above its junction with the Mantedu. Cretaceous rocks extend to a few hundred feet from the top on this gorge also, resting on metamorphics, and appear at the same level on the opposite side beneath the village of Batao. These rocks extend to the hill on which Lakadong stands, about half way up which nummulitic limestone occurs, overlaid by sandstone with coal.

Lakadong coal.

The coal workings here appear to be in much the same state now as at the time of Dr. Oldham's visit in 1853 (Sel. Rec. Ben. Govt., No. XIII., p. 45), as since then very little coal has been extracted. The different holes have been driven into the coal as far as is possible without having to support the roof with timber, and the expense of this, together with the increased cost of labour and of carriage to the plains, in 30 years, would probably prevent the coal being worked with profit at the present time. The headman of the village told me that 500 maunds had been extracted last year, and sent down to the plains, but he could not tell me what the cost of extraction and carriage was.

3. Lakadong to Nokhara.—To the north of Lakadong on the path to Umrasiang cretaceous rocks forming low scarped hills extend to the gorge of the Saichampa, about half way down which metamorphic rocks appear and a similar section is seen on the opposite bank. The lowest cretaceous beds here are ferruginous sandy clays. Close to Umrasiang village I observed a circular pit, with perpendicular sides in the sandstones, 50 or 60 feet deep, and as many in diameter, probably due to the washing away of the clays beneath through a fissure and the consequent falling in of the sandstones above. The cretaceous rocks continue to a hill about 2 miles east of Umrasiang, near the top of which nummulitic limestone forms a steep scarp to the north. This hill is flat-topped, consisting of sandstones similar to those at Lakadong, but without any traces of coal till near the village of Nokhara, where there is a seam 1 foot thick resting on carbonaceous shale, but of no great extent. To the south the ground falls gradually to the edge of the streams running into the Lubah, where limestone again appears. In many places near Nokhara I noticed large funnel-shaped hollows, 30 or 40 feet deep, caused by underground denudation of the limestone.

4. Nokhara to Kampat.—Proceeding to the north from Nokhara on the path to Satunga after descending the limestone scarps to the north, a small outlier of limestone is passed near the village of Umluper. To the north of this the plateau is much more broken than to the west as far as the Laterkap river, in the gorge of which metamorphic rocks occur again. Near the village of Nongtoma (not marked on the map, but about 2 miles to the south of the Laterkap) I passed a funnel-shaped hollow similar to those at Nokhara, but could not find any limestone below it. To the north of the Laterkap cretaceous

rocks extend without a break to Satunga, where they contain a seam of coal.

Coal at Satunga.

Its outcrop is seen at the head of a small ravine to the north of the village. A vertical section, in descending order, is as follows:—

	Ft.	In.
Sandstone and shale, about	20	
Coal	1	9
Shale, carbonaceous at top, less so towards the bottom	5	
	26	9

The hill side slopes rapidly upwards from the top of the section.

Two outliers of nummulitic limestone occur a short distance to the west of Satunga. To the east the ground slopes downwards for about 4 miles to the village of Kampat, which lies at the foot of a well-defined ridge running north and south. The lower 300 feet of this are nummulitic limestone, with a slight dip to the east, resting on a wavy surface of cretaceous rocks, and extending to north and south as far as one can see.

This is capped by upper tertiary sandstones resting on the limestones, and extending to the top of the ridge 500 feet above Kampat. These rocks, though they occupy the same position with regard to the limestone as the coal-bearing rocks of Lakadong and Nokhara, do not contain any traces of that mineral, nor is it found further to the east. They are fine-grained, highly ferruginous sandstones, the lower beds containing numerous grains of pisolitic iron ore. The sandstones rest conformably on the limestone, though in places there are local unconformities, due to underground denudation of the limestone. According to Colonel Godwin-Austen these rocks contain numerous minute fossils. From the top the ridge is seen to bend round to the north-east, striking for the Kopili. A vertical section of the ridge is as follows, in descending order:—

		Ft.	Ft.
Upper tertiary.	Fine-grained ferruginous sandstones, with a little pisolitic iron ore near the base, about		200
Nummulitic limestone.	Massive limestone, becoming shaly and earthy towards the top, about	70	
	Massive limestone, shaly and earthy at top	160	
	Thin bedded earthy limestone	70	
			300
			500

On the eastern side of the ridge limestone is met with again at about 230 feet from the base, and continues to the level of the valley in which Nonklir stands. This is a flat, alluvial plain about 2 miles broad at this part. From the top of the ridge the limestone is seen to form a fringe at the base of the hills surrounding the valley, extending to the south as far as the base of Jakorsing hill, the boundary between the limestone and upper tertiaries being easily traced, as the former is covered with thick tree jungle while the sandstones above are nearly bare of trees and covered with grass.

The limestone visible at the base of the ridge to the east of Nox reduced to 130 feet in thickness, and is succeeded by upper tertiary sandsto shales rising to 550 feet above the valley. In the next valley to the east li does not appear, nor is it again found anywhere to the east.

5. Kampat to the Hot Springs on the Kopili.—Following the limestone north from Kampat, it is found to occupy nearly the whole of the space l the Kharkor and Kopili rivers, cretaceous rocks forming a fringe at the the limestone scarp. It is capped by upper tertiary sandstones bene village of Pala, which is situated on a spur of Pomlana 3,754 feet above s To the west of the Kharkor are numerous scarped outliers of limest largest overlooking a level plain of cretaceous rocks to the north of Munch This plain extends to the foot of a lofty ridge of metamorphic rocks (on wl village of Khaushinong stands) running north-east to the Kopili. Th morphics cross the Kopili about 1 mile north of the hot springs and f ridge running east and west, called Khandong hill. The Kopili forms a su of very fine falls and rapids over these rocks.

The nummulitic limestone crosses the Kopili to the north of Umkerpo bends round to the east parallel with the metamorphics of Khandong l extends to the east as far as the flanks of Phulong hill, but it does not in the valley of the Diyong still further to the east.

The valley between it and the metamorphics is occupied by cretaceou except at the hot springs, where a small area of limestones has been let d faults among the cretaceous beds.

6. The hot springs.—The following notice of the hot springs is given Oldham's catalogue of the thermal springs of India (M. G. S., Vol. XI p. 54):

" KOPILI.—Latitude 25° 31′; Longitude 92° 40′; Temperature 122°.

" On the right bank of the Kopili, three days' journey from Silchar, a half day's journey from Jawai. The water is not saline but only hot. Returns.—Captain (now Lieutenant-Colonel) Godwin-Austen, however, s of the spring in a private letter, says it is strongly saline."

The distances given above are not quite accurate as the spring is seven days' journey from Silchar and two from Jawai. There are three sprin in transverse gullies on either side of a stream running west into the Kop about 100 yards from the latter. Of these the one to the south is consi larger than the other two. Its temperature I found to be 128°. The wa not the slightest saline taste, or indeed a taste of any kind, rather res distilled water. The temperature of the two small springs to the north w and this water also was perfectly tasteless. All these springs lie on the boundary between the cretaceous and nummulitic rocks. The stones ove the water runs are covered with a very thin white deposit, probably cal That this deposit is not thicker, is probably due to the fact that the Kopili the rains rises several feet above the level of the springs, and so washes i

7. Upper Tertiaries of the North Cachar Hills.—Beyond the limeston to the south-east of the hot springs upper tertiary rocks extend in an u mass to the Barail range above Asalu. As far as the police outpost of G

these rocks are horizontal, or nearly so, consisting of fine-grained sandstones and shales. It is in the valley of the Mahur, to the east of Gunjong, that the change from the generally undisturbed condition of the newer rocks on the Shillong plateau takes place, the upper tertiary rocks to the east being everywhere greatly disturbed. The transition does not take place so abruptly as on the southern edge of the plateau, where the newer rocks are bent down suddenly in a uniclinal curve into the area of disturbance; but it is well marked, the rocks at Gunjong having a slight inclination to the east, while in the Mahur valley they are sharply contorted and at Quilong on the opposite side are nearly vertical. The boundary between the disturbed and undisturbed sweeps round to the west, along the Jatinga and Lubah valleys, until it coincides with the east and west strike of the edge of the Shillong plateau.

In these beds, in the Mahur valley, I found a few insignificant strings of coal, but no where did I come across any workable quantity.

Quilong limestone.

Before leaving Calcutta in November I had heard that there were considerable deposits of limestone near the outpost of Quilong, and while there I went in search of them. They are situated on a small stream running into the Langting, to the north-east of Quilong, and about 1,500 feet below it. The rocks here are shales dipping at 20° to north-north-west, and the stream has deposited a bed of calcareous tufa on the upturned edges of the shales. This limestone is from 1 to 2 feet thick where thickest, and is of small extent. A small quantity was burnt on the spot several years ago when the outpost at Asalu was being built, and the remains of it, which are still used to supply Quilong and Gunjong with whitewash, are to be seen in the jungle close by. Similar deposits also occur in the valleys near Gunjong, but none has been burnt there.

Iron.

The natives on the northern border of these hills informed me that in former times they used to extract iron from a highly ferruginous drift which is found in most of the hill streams. But the manufacture of it has entirely died out, and at Walsalai a large Kuki village to the east of the Dirjung, I found them making implements with iron brought from Calcutta.

The iron ore deposits are very scattered, and would probably not repay systematic working.

On Native Lead *from* Maulmain, *and* Chromite *from the* Andaman Islands; by F. R. MALLET, *Deputy Superintendent, Geological Survey of India.*

Native lead.—Amongst a number of ores from the neighbourhood of Maulmain, in Burma, lately sent to the Geological Survey Office by Mr. G. H. Law, is one of a somewhat unusual character. It is a carbonate of lead, breaking with a rather largely facetted crystalline fracture, and having a bright red colour due, apparently, to an intimate admixture of minium. The mineral contains small cavities lined by minute white crystals of ordinary cerussite, and some of the cavities are partly filled with metallic lead. The above-mentioned substance has the appearance of a natural product, but the precaution was taken of writing

to Mr. Law on this point, and in reply he states that it is "natural and not artificial." As native lead is a mineral of rare occurrence, its discovery in a new locality is worth putting on record.

Red carbonate of lead similar to the above, except that the native metal has not been observed in association with it, has been found also in the Hazáribágh district of Chutia Nágpur.[1]

Chromite.—During the present month a block of ore was to be sent to the Geological Survey Office, for examination, from the Officiating Chief Commissioner of the Andaman and Nicobar Islands. Mr. M. V. Portman, Extra Assistant Superintendent, who visited the place where it was found, writes: "About 100 yards south of the village of Chuckergaon, on the bank of a small stream, was a mass of ore about 9 inches thick and 4 feet long. It was lying on the surface of the ground. On removing it, and digging round and underneath it, the rock appeared to be a coarse sandstone strongly impregnated with iron. No more ore was found on this spot, though it again appears in two places further down the valley in some considerable quantity, several hundredweight having been brought in. On examination of the rocks within a radius of 300 yards, I found granular and highly crystalline limestone, intersected by views of calcspar in some instances 4 inches thick, diorite, porphyritic trap, and coarse ferruginous sandstone." Chuckergaon, the village mentioned, appears to be close to Port Blair.

The ore proved on examination to be chromite. As this mineral is usually found in serpentine, and serpentine is known to occur in the neighbourhood of Port Blair, there is a strong probability that the Andamanese chromite is no exception to the general rule. "Serpentine and gabbro are found largely developed south of Port Blair and on Rutland Island, and are doubtless intrusive. A "micro-crystalline syenite" was noticed in one locality by Mr. Kurz; it is doubtless a form of the dioritic rock found locally associated with the serpentine in Pegu.[2]" It will have been remarked that Mr. Portman observed diorite, &c., close to the place where the chromite was found.

As chrome iron ore (chromite), of average quality, is worth about £10 a ton in England, the Port Blair mineral, if obtainable in considerable quantities, is well worth attention.

Notice of a Fiery Eruption *from one of the* Mud Volcanoes *of* Cheduba Island, Arakán.

The following correspondence respecting an eruption from one of the Cheduba mud volcanoes is published in continuation of similar records[3]:—

F. R. MALLET.

From Captain F. D. RAIKES, *Deputy Commissioner, Kyouk Phyoo, to the Commissioner of Arakán, Akyab, dated Kyouk Phyoo, 2nd May 1883.*

I have the honour to forward a free translation of a letter received from the Myooke of Cheduba, in which he reports that the volcano in the Minbyin Circle of his Township gave

[1] Records, G. S. I., Vol. VII. p. 35.

[2] W. T. Blanford, Manual of the Geology of India, part 2, p. 733.

[3] *Supra*, Vol. XI, p. 188; XII, 70; XIII, 206; XIV, 196; XV, 141.

on the 23rd March last. The Myooke's report is dated 23rd April, and was yesterday. I am about to start for Cheduba, and should anything new regarding be ascertained, a further report on the subject will be submitted.

ng Tsau Oo, Myooke of Cheduba, to the Deputy Commissioner, Kyouk Phyoo.

report that having been informed that there was an eruption of the volcano in n Circle of this Township on the 23rd March last, I sent the following Moung Wine, Yazawoot Gonug of Minbyin, for answer. His answers are given question :—

Question.		*Answer.*
ruption burst out violently?	...	The eruption was sudden and violent, gradually subsiding.
adual?	...	
height did the flames rise?	...	About 900 feet (*sic*).
s the circumference of the flame?		About 450 feet.
g did the eruption last?	...	About 9 minutes.
lames give out any smell?	...	Yes, that of earth oil.
e much smoke?	...	Little smoke in comparison with the flame.
l alone thrown out?	...	Mud and gravel, no other mineral.

NOTICE.

ion from wells in the North-Western Provinces and Oudh, by CAPTAIN LIBBORN, B.S.C., *Executive Engineer, on Special Duty, Department of culture and Commerce, N.-W. P. and Oudh.* In the Professional Papers dian Engineering, 3rd series, Vol. I, p. 103, Roorkee, 1883.

ll the visible and measurable elements of the investigation undertaken Clibborn, the method adopted seems to have been thorough, and the ained must be of great and permanent practical service. By the adop- unit of work, with values determined by careful experiment, he has comparable form a chaos of information upon the subject in hand nce to the depths and capacities of wells and the processes of 'lift' in as moreover applied his method over an immense field of observation, right across the Gangetic plains from the terai on the north to the scarp on the south, and some 250 miles broad between Agra and The sound facts thus accumulated must indeed be accepted as a main n to the question in view; but there are considerations of fundamental n of collateral importance regarding the distribution and the supply of lable, upon which much light might have been expected from such a observation, and upon which the remarks offered by Captain Clibborn ly defective but misleading; because, no doubt, the facts concerned are visible or measurable. This branch of the subject has come within the of the Geological Survey, so that some notice of the matter is here

question of artesian sources in the plains of India has been discussed at h in these Records (Vol. XIV, page 223, *et seq.*), and the probability

of their occurrence asserted. In the paper under notice, Captain Clibborn professe to show that artesian action is quite incompatible with the strata of the Doa It is necessary to quote two paragraphs to make the position clear :—

"22. Leaving out of the question for the present wells which receive a supply from perc lation, we will consider the case of what are usually termed spring (*bom*) wells, which should l sunk so as to have the end or lower ring firmly imbedded in the *mota* (layer of clay), therel (if a masonry well) shutting out from direct entry all water overlying it. Now the general adopted theory regarding the use of the mota for water supply is that it acts as an artesia basin, and that the supply entering the well through an orifice which is bored in the cla is a veritable spring, caused by the pressure of water from the collecting area of the basin.

"23. The facts which are alleged to support this theory are *first*, that until the mota i reached, the water-supply is easily exhausted. This is contradicted by experience. *Secondly* that when the hole is bored into the mota a copious supply enters the well, often causing dang to the workmen if they do not escape quickly, and sometimes rising above the mouth. But th artesian theory pre-supposes the comparative continuity of the mota, which is at variance wit the universal testimony of cultivators, and the facts alleged are easily explained on other ground *vide* paras. 26—30. It will also be shown that artesian action is quite incompatible with the strat of the Doab."

3. This last sentence is a general proposition, and would properly be taken t include the whole formation concerned. We are by no means sure that Captai Clibborn does not intend it in this sense, for the strata at greater depths are n doubt of the same pattern as those exposed; but as the facts immediately quote (paras. 24-25) regarding the contour of the sub-soil water (although they ar somewhat irrelative to the immediate question) can only refer to the groun above the level of the rivers, and as no direct allusion is made to deeper artesia springs, we may restrict the discussion to the narrower issue; and upon this it not difficult to show that Captain Clibborn does not seem to understand the need ful conditions of evidence or of argument. We are by no means concerned t prove that the *bom*-wells are artesian; only, if the facts asserted of them ar correct, they are essentially of that nature.

4. The first fact refuted by Captain Clibborn, in his paragraph 23 just quoted may be said to be irrelative; but even upon the theory he himself adopts i is not easy to see how experience can contradict that a deeper well, tapping a larger segment of the same water basin, is less easily exhausted than a shallower one. For the 'alleged fact' of the water rising above the surface Captain Clibborn would have done well to introduce the plain contradiction argument, as it would be impossible to explain it otherwise than as artesian; and we need hardly say that no attempt is made to do so. For the remaining and essential point, that water does rise from below the clay, Captain Clibborn adopts a double course, to vitiate the opposite view and to offer a simpler explanation; but in both lines of argument he begs the point at issue.

5. It may well be true that the clay band is not everywhere continuous; but it is altogether too dry a statement to say that the artesian theory pre-supposes this continuity, though such an impression would readily be conveyed by the ordinary text-book exposition of artesian conditions, dealing with strongly-marked examples. Partial artesian action is always possible when percolation along the planes of bedding is much more easy than across them, and this seems to be a general

character of stratification independently of any visible impervious beds. In anticipation of objections such as this, when the proposal for artesian borings in Upper India were first brought forward (in 1867), instances were quoted showing the compatibility of artesian springs with great irregularities (want of continuity) of the deposits (Selections, Government of India, Home Department, No. CLXXVIII, p. 48. 1881.) This condition then, as framed by Captain Clibborn, is artificial.

6. The first item in the housewife's receipt for hare soup, beginning with the injunction to catch your hare, is of equal importance in discussion—to fix your fact before beginning to talk about it. When the *bom*-wells were quoted as an apparent instance of partial artesian action, it was assumed that the engineer who described the phenomenon was aware of the fact that if a tube with a diaphragm over the end be depressed into water the fluid will rise to the same level inside when the diaphragm is pierced; also, that in bringing the fact of the well to notice he was satisfied it was not an instance of this familiar experience, that in fact the waters above and below the clay did not stand at the same level, and were distinct, of which indeed he did give strong independent evidence in the wholly different nature of the water above and below the clay, and this is really the essential question at issue—whether or not the two water strata are distinct. It appears however that Captain Clibborn has an equally implicit conviction on the other side, for he decides the point with a simple assertion (paragraph 27), "the head is the difference of level between the water inside and outside the well;" and he seems to think that the only evidence needed on this score is to show how the water would perform the passage, the fact of free communication between the water tables having been assumed. This is the 'explanation on other grounds,' for which we were referred to paragraphs 26—30. It is introduced as 'a theory, advanced by Mr. J. S. Beresford, Executive Engineer, Irrigation Department,' and consists of an exposition, with the aid of numerous diagrams, how when sand is forced up with the water from below through a hole in the bed of clay, a hollow must be formed in the place vacated by the sand, and further how in passing from the upper to the lower stratum the water will obey the laws of mechanics. It is all quite beautiful in its simplicity, not excepting the omission of the one thing needful, even as a blank assertion, that the natural water levels of the two strata are constantly one and the same. Upon this crucial point (which would have set the whole matter at rest) one would think Captain Clibborn might have picked up some information during his extensive exploration, either by direct observation (not a very difficult matter), or 'from the universal testimony of the cultivators;' without it his 'theory' is all in the air.

7. This question of the artesian character of the bom-wells is a trivial matter in itself, having little or no bearing upon the existence of deep artesian springs, and it would hardly have deserved notice here but that the essential feature of it—the independence of the water tables—is of much practical importance on several counts, and has received notice in these pages (Vol. XIII, p. 273) in connection with the reh scourge. In that discussion, in which the Irrigation Department is deeply implicated, the more or less complete and permanent sepa-

ration over very large areas of the parasitic water (as the French call it) of the sub-soil and the deeper ground water, has passed without challenge as an admitted fact, presumably on the experience of the engineers and the universal testimony of the cultivators; and one might have thought that the investigation of the range of such conditions would have been an express object of Captain Clibborn's researches. It is clear that this fact (if it be one) of the lower water being sweet while the upper is saline, would afford an independent and sufficient proof of the separation of the water tables and of the so far artesian nature of any rise of water from below the clay; but it is not included in the facts bearing on this point noticed by Captain Clibborn, though it certainly has been alleged in that connection. This might be an oversight; but it is not intelligible how such a fact (or statement, if it be not a fact) can have escaped prominent mention in connection with the investigation under notice, which included extensive tracts of reh land; yet it is not even alluded to. Can Captain Clibborn have found it out to be a popular delusion? His explanation of the bom-well performance would certainly imply that it is not a fact.

8. That the notion of the extensive occurrence of an impure sub-soil water permanently separated by clay beds from the ground water is not quite exploded may be gathered from an excellent Report on Reh Swamp and Drainage, by Mr. E. E. Oliver, in the same number of the Professional Papers, where quotation is made (p. 9) of a description of such conditions in connection with reh land. The same is described from actual observation over a large part of the Doab in an early notice of the *bom*-wells in the 'Correspondence relating to the deterioration of lands' (Selections, Government of India, P. W. D. No. XLII, 1864, p. 94).

9. Having mentioned Mr. Oliver's paper, we may venture to notice what migh be thought a slight confusion in the presentation of the theoretical aspect of th question, in Sections IV, *Chemical composition and analysis*, and V, *Physical theori advanced;* and confusion on this side is at the bottom of most practical mistake leading often to incalculable waste of effort and of money. It is rather under th latter of the above sections that one would look for an account of the origi of reh, yet the only explicit statement on this most important point appea casually in the opening sentence of Section IV, and the hints given of it i Section V are extremely obscure. The simple performance which results in crop of reh scarcely deserves to be condemned under that much abused wor 'theory,' it is so obvious when witnessed. Though unacquainted with th word 'capillarity,' any cultivator probably has a sound proximate notion the reh crop, how it is connected with poisonous sub-soil water which the su sucks up leaving the reh on the surface; he knows well too that the bad wat would not be there if it could get away, and what prevents it. So far Gener Strachey's 'physical theory,' which Mr. Oliver quotes with approbation, coul not well help being 'lucid'; but it professed to be "quite sufficient to accou for the whole thing" (Selections, *l.c.* p. 57), and as such it is probably the mo hazy thing General Strachey ever wrote. Even the few sentences quoted b Mr. Oliver are rendered mischievous by the false conception they imply regar ing the origin (or no origin) of the reh—that these salts are in the soil an

have been there always, having come with the silt from the mountains. He even goes out of his way to make the question occult by the interference of segregation, as in the production of flints in the chalk, saying "so too it seems highly probable that from some physical cause the sulphate of soda, &c., have accumulated in certain places on the alluvial deposits of Upper India." Yet this was written in 1864.

10. In conclusion we may point out a slight misconception where Mr. Oliver notices (p. 10) an apparent contradiction or qualification of opinion as expressed in the following quotations from Mr. Medlicott's reports—"As far as the facts before me are a guide, I am inclined to the opinion that the canal water is *the chief* source of the salt. I am now speaking of the lands newly affected" (1862); and "that the reh scourge existed widely before the canals were thought of, and *this reh constitutes immensely the greater part of what has now to be dealt with*" (1878). In the first place, the two statements pointedly refer to different ground, new and old reh land; but even if they referred to the same area the statements are not logically comparable and might have been written consecutively at either period without discrepancy, for they explicitly refer to different things, one to the stock of reh in hand, the other to the source of reh. A man might surely have little cash in his pockets though having a large income, or *vice versâ*. As a general statement, however, the first one was somewhat misleading, although in some land the possible sources of fresh reh would certainly be less than in the irrigation water. The exaggeration of the partial statement was provoked by the dogma then universally accepted that the canal water acted solely as a vehicle.

H. B. MEDLICOTT.

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October 23rd, 1883.

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MDCCCLXXXIV.

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1884.

CONTENTS.

CORRIGENDA, Vol. XVII, Part 2.

Page 66, line 22, *for* dolerite, *read* domite.

„ 67, „ 10, *before* cavity, *insert* liquid.

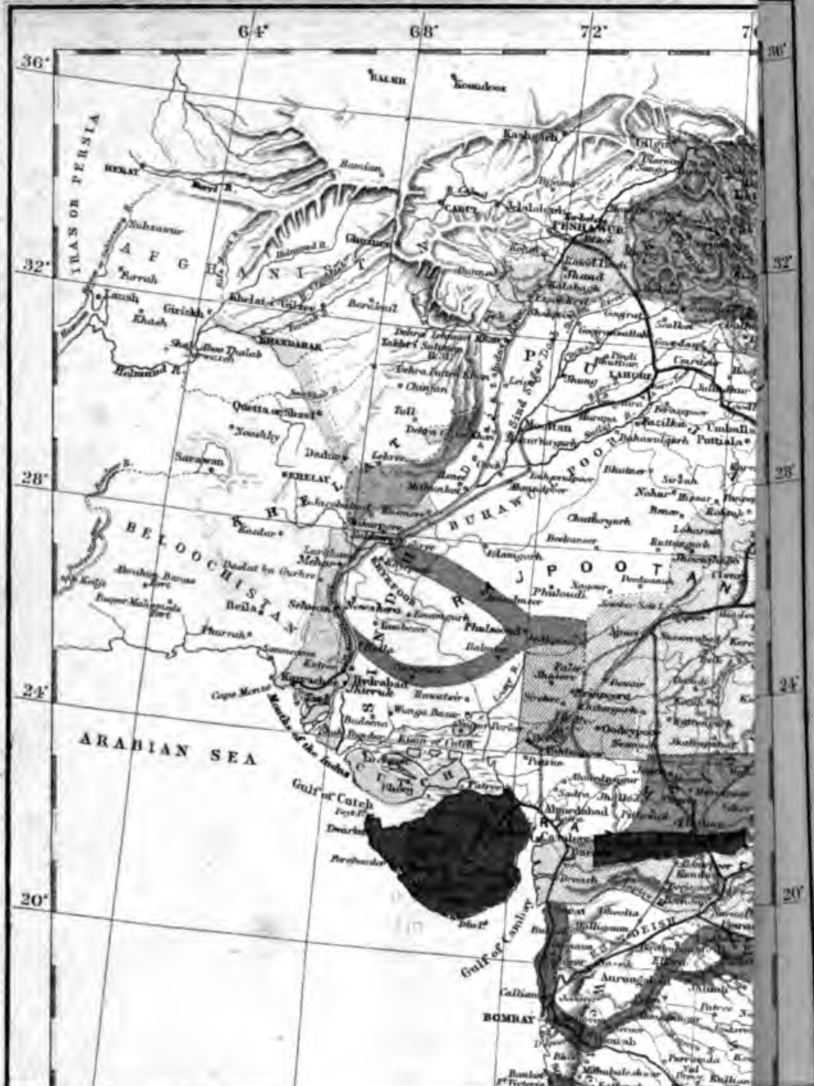
„ 67, lines 11, 12 and 13, omit the sentence beginning with "The cavity", and ending with "its present size".

„ 67, line 16, *for* "empty portion of", *substitute* liquid in the.

„ 69, „ 6, *for* formed, *read* found.

„ 69, „ 8, *for* arrangements, *read* arrangement.

„ 70, „ 7, *before* flank, *insert* the.



36°
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IRAN OR PERSIA
AFGHANISTAN
BELOOCHISTAN
ARABIAN SEA
PUNJAB
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BUHAWULPOOR
Gulf of Cutch
Gulf of Cambay
BOMBAY
HERAT
BALKH
CABUL
PESHAWUR
KANDAHAR
Quetta or Shawl
KHELAT
Kurrachee
Hydrabad
LAHORE
Ahmedabad
Dadur
Sarawan
Bamian
Ghuznee
Mooltan

RECORDS

OF

[E GEOLOGICAL SURVEY OF INDIA.

1884. [February.

REPORT OF THE GEOLOGICAL SURVEY OF INDIA AND OF THE GEOLOGICAL

CORRIGENDUM, *Supra*, VOL. XVI,

page 179, top line, for *has* read *have*.

the gneissic mass of Purgial mountain which separates Hundes from te obstruction encountered from the unruly condition of the people on of the frontier was even greater than in previous seasons; we must only a sketch survey as all that is possible in that direction for some time to is further very satisfactory that Mr. Griesbach has been able to link rith that of Dr. Stoliczka in his typical sections of Spiti by a trip over h and Manirang passes. For some important horizons he has satisfied the identity of the sections in Spiti and Hundes, particularly the occurpiti of full representatives of the lower triassic groups, not noticed by We have thus strong evidence for the presumption already made that t separation of these basins is largely, if not altogether, a feature of e; an example on the largest scale of the longitudinal waving of the vation which has been frequently noticed in the detailed structure of ntains.

T-I-SULEI-M.

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Annual Report 1883.

II.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

1.] 1884. [February.

AL REPORT OF THE GEOLOGICAL SURVEY OF INDIA, AND OF THE GEOLOGICAL MUSEUM, CALCUTTA, FOR THE YEAR 1883.

HUNDES: r. Griesbach.

e extra Peninsula area.—Of work done during the past season, Mr. Griesbach's would be popularly considered the most interesting, as dealing with the main Himalayan range and the well-known formations there displayed on so grand a scale. tunately no matured abstract of his observations is yet available, as Mr. ach had to make all haste from Tibet late in October to join the expedi-the Takht-i-Suleiman, and he is still engaged on the north-west frontier. d however brought his particular undertaking to its intended conclusion, completed the survey of the Hundes basin to its western limit on the of the gneissic mass of Purgial mountain which separates Hundes from The obstruction encountered from the unruly condition of the people on ides of the frontier was even greater than in previous seasons; we must only this sketch survey as all that is possible in that direction for some time to It is further very satisfactory that Mr. Griesbach has been able to link rk with that of Dr. Stoliczka in his typical sections of Spiti by a trip over abeh and Manirang passes. For some important horizons he has satisfied f of the identity of the sections in Spiti and Hundes, particularly the occur-n Spiti of full representatives of the lower triassic groups, not noticed by ka. We have thus strong evidence for the presumption already made that sent separation of these basins is largely, if not altogether, a feature of ance; an example on the largest scale of the longitudinal waving of the f elevation which has been frequently noticed in the detailed structure of nountains.

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We have at last got a bit of critical study from that most obscure region, the Lower Himalaya, in Mr. Oldham's work of last season in Jaunsár (Records, Vol. XVI, pt. 4). This remark leaves out of count Mr. Mallet's very thorough study from the same region in Sikkim (Memoirs, Vol. XI, 1874), the distance is so great (700 miles), and the details so different; also Colonel McMahon's most excellent observations in the Simla area (Records, Vol. X, pt. 4, 1877), on the grounds that they are not comparable, being only notes made during official tours of inspection. On similar grounds I would claim partial exemption for my own notes (Memoirs, Vol. II, pt. 2) published in 1864. I was then especially engaged with the Sub-Himalayan rocks, and my notes upon the older formations were taken on casual traverses of the ground; but I put them into the best form I could (unfortunately not a very lucid one) with a provisional scale of formations. There would be no risk in so reasonable a proceeding, but for the delight some people take in figuring as correctors of what it gratifies them to call 'error;' and it is so easy in a reference to omit all notice of the saving clauses of the context, or to quote a passing opinion as if it had been a matured judgment. It was my early connection with the college at Rurki that gave me the opportunity of Himalayan work, and since I left it (in 1862) no regular survey has been undertaken in this ground until now, though it is here, as I have often explained, that we must hope to find a clue to the whole Lower Himalayan region.

JAUNSAR: *Mr. Oldham.*

After a preliminary view of the Simla section, Mr. Oldham settled down upon Jaunsár, a British district between the Tons and the Jamna, because there he would have the advantage of a fairly good map on a sufficient scale, the Atlas maps of the general area being very defective. The result has been no small surprise, which I will briefly explain. The sequence of formations in the Simla section is apparently a simple one in itself, however complicated by disturbance. There is at top a strong limestone, which takes its name from the Krol mountain; it is underlaid with apparent conformity by a great thickness of shales, slates, and flags, sub-divided by one small but very persistent band of limestone and conglomeratic quartzite known as the Blaini group. It was thought that these rocks extended indefinitely eastwards, and Mr. Oldham has himself recognised a known outcrop of the Blaini group far to the east of Jaunsár, beyond Mussooree; yet in the Jaunsár section, which takes in a full slice of the region from the tertiary zone to the gneiss, and is only 50 miles east of Simla, an almost completely new series of rocks is introduced, the limestone of Deoban mountain, north of Chakráta, being taken with some doubt to represent the Krol rock. It rests unconformably upon a great series of slates and quartzites with subordinate limestone; but in this Chakráta series none of the infra-Krol sub-divisions have been recognised. This discrepancy must, of course, stand; but it seems more likely to be explained as a variation of deposition than as an entire change of systems. Unconformities, too, are of precarious certainty where disturbance has been so intense. But the most interesting feature in the Jaunsár work is the introduction of two separate and entirely new groups. It has always been known that a great gap existed between the tertiaries in the Simla section and the Krol group, for which no age later than the trias has been conjectured; but no

intermediate deposits had been detected. In Jaunsár Mr. Oldham introduces two unconformable and almost wholly detached groups above the Deoban limestone. One, the Mandhális, may be of upper secondary age; but the other, the Báwar, is taken to be middle tertiary, as it exhibits little or no disturbance, although highly metamorphosed; it lies to the north, close under the main gneissic range. All this may seem a little wild, but a perusal of Mr. Oldham's paper will show that he thoroughly understands what he is about, and has completely protected his position; that if he scorns grooves and is somewhat reckless of antecedent probabilities, he has on the other hand a wholesome faith in close observation and sound reasoning.

CHAMBA: *Colonel McMahon.*

Colonel McMahon continues to favour us with his studies in the intervals of business. His determination of the truly basaltic character of the bedded trappean and trappoid rocks associated with the slates of the Lower Himalaya removed an awkward uncertainty; but his later decision that much of the granitoid gneiss of the Himalaya must be regarded as a truly intrusive rock is a most valuable discovery, as giving a clue to structural features that were almost impossible of explanation on the supposition of the rock being stratified by original sedimentation. When first describing this gneiss in the Simla region, Colonel McMahon remarked that "the internal structure of the rock is that which has usually been described as characteristic of an igneous rock" (Records, Vol. X, p. 222), and his later more leisurely study of the same rock with its attendant contact phenomena at Dalhousie has forced upon him the conviction that it is intrusive and must properly be called gneissose granite (Records, Vol. XVI, p. 129). His arguments are mainly drawn from the microscopical examination of petrological characters, and depend a good deal upon the more or less obscure conditions of the process of metamorphism and contact action, whereby very similar results may be accomplished in very different ways;[1] still the arguments are very forcible, and when backed by the more certain evidence of structural features, they seem to me conclusive. Despite the wonders performed by flexure of strata in mountain regions, the structural features presented by this rock in certain cases were impossible of satisfactory explanation on the supposition of its being really stratified gneiss. The Chor mountain in the Simla region and the end of the Dhuladhár ridge at Dalhousie are instances. It is true that by Herbert originally, and by Strachey subsequently, the Chor was mapped as granite; by overlooking everything but the crystalline texture they hit upon the right name; but had they represented their conception of it in section, it would no doubt have assumed the conventional form of a vertically intrusive rock; whereas in reality the rock is not only foliated and roughly bedded, but it conforms in lie to that of the surrounding strata, presenting a steep south-westerly outcrop and a moderate dip conformable with that of the overlying schistose slates; the puzzle being that it has no continuity in strike, the outcrop being about as broad as it is long,

[1] I long ago brought to notice an instance of a perfect ternary granite where it can only have been formed by solution or hydrometamorphism, without intrusion or disturbance, or any conditions usually associated with the word 'plutonic.' See Memoirs, Vol. III, p. 17, and note by Professor Haughton, Journ. Geol. Soc., Dublin, I, p. 87, 1864-65.

nearly 7 miles. The recent recognition of the fact that those characters of quasi-stratification are compatible with a truly granitic and intrusive origin, removes all these difficulties, and thus establishes a strong claim for acceptance.

KASHMIR: *Mr. Lydekker.*

Although Mr. Lydekker's work in the North-West Himalaya closed two years ago, and was duly noticed as it came out in his progress reports, the recent publication of it (Memoirs, Vol. XXII) in a connected form and with a map of the whole area requires further remarks. But for this compilation the work would be in a manner lost; and Mr. Lydekker has performed his difficult task in some respects most creditably,[1] for it demands considerable art to put a mass of very crude material into presentable form, and this has been done; the volume now published gives an excellent general view of the distribution of the rocks over an immense area of very inaccessible ground. In view of future operations it is however necessary to indicate explicitly how superficial this work has been. Mr. Lydekker remarks, and it is quite true, that anything like a study of the whole ground would demand a hundred-fold the time that has been given to it; we are told on almost every page that data are wanting to decide some point or other, showing a fair perception on his part of what was needed, but this only makes the almost total absence of critical landmarks the more disappointing.

Although a considerable additional area of the sub-Himalayan region was mapped by Mr. Lydekker, his attention was least directed to those rocks, and he has added nothing to the difficult question of their classification; indeed, the grouping he adopts (p. 83) is neither congruous nor properly geological, the ruling question regarding them being whether the repetition of more or less similar deposits in successive zones up to the innermost boundary of the region are representative or distinct formations; and had he any real apprehension of the position, he would not have remarked (p. 13) that the views regarding the upper tertiaries in our original work in this region (Memoirs, Vol. III) had been modified. It is true that a correction was published (Records, Vol. XIV, p. 169) of an erroneous observation of an important contact-section of the Nahan-Siwalik boundary, and that great stress had been laid upon that observation because it would have been an absolutely final settlement of an important dispute; but in publishing the correction it was expressly stated that all the other evidence remained in favour of the view originally taken of that boundary, that it was primarily an unconformable contact. By far the most important and definite result of observation as bearing upon Himalayan history is that enunciated at page 121 of Mr. Lydekker's memoir, but it would not be gathered from the context that this result had been very clearly concluded from our first study of those mountains; that although the Himalayan area had been elevated and defined, and the rocks deeply denuded before the eocene, little or no contortion of the rocks had attended that disturbance (see Memoirs, Vol. III, p. 174, 1864). Mr. Lydekker has now extended this observation to the tertiary basin of the upper

[1] I must take exception to and apologize for the note on page 273 and the "(*sic*)" on page 274 of Mr. Lydekker's memoir, which was printed in England. I would be the last to check plain criticism of bad work, but to reproduce and point the finger at paltry errors of press-reading in a quotation worthy of all respect, is a display of critical acumen that I trust may not again disfigure the pages of our Memoirs.

Indus; but there is one important reservation that he has not noticed. In his section on page 101, the tertiary strata lie at right angles to those of the gneiss; now the apparent conformity of the palæozoic rocks to the gneissic series is a constant subject of remark and puzzle with regard to the presumable existence of a prepalæozoic gneissic mass; if then the Indus tertiaries are in pseudo-conformable relation to the palæozoic strata there, the gneiss of the Skirbichan section would be a better identified example of that archæan gneiss than any of those suggested in Chapter IX.

On page 127 Mr. Lydekker makes some very judicious reflections upon the difficult question of the correlation of formations in Europe and in India, as introductory to the gigantic compromise he has to make in clubbing into one 'system,' 'the Zánskar system,' the eight formations, ranging from lower carboniferous to cretaceous, distinguished by Stoliczka at the east end of the Zánskar basin itself. We must allow a good deal for the reputed extinction of fossils to the westward in these continuous deposits, nor should we complain of a temporary compromise had we found even a few critical landmarks for a classification which we must believe to be possible in that ground. The map does attempt a three-fold division of the 'system' into carboniferous, jura-trias, and cretaceous, the three little patches of the latter being those marked by Stoliczka; but a map on so small a scale can only be an index to the text.

The 'Zánskar system' is itself described as transitional with the underlying 'Panjál system' of lower palæozoic rocks, and these again are for the most part inseparable from the schistose metamorphic or gneissic rocks. In the Manual (pp. 626-7) the term 'central gneiss' was tolerated upon the intelligible grounds that we were then supposed to have in actual evidence two gneisses; one in the main Himalayan range, as testified by Strachey in Hundes and by Stoliczka in Bissáhir to be in abrupt original contact with the infra-silurian azoic slates; and another in Rupshu, as testified by Stoliczka to include all the lower palæozoic formations. For the former the name 'central' was not inappropriate, in the sense of local fundamental or local archæan. Later observation both in Hundes and Bissáhir asserts that on the north flank of the main range there is complete gradation of metamorphism from the gneiss to the slates; so it would for the moment appear as if we had only to deal with one period of metamorphosing action of variable range; or at least the original demarcation of two gneisses is not sustained. Under these circumstances, as based upon an assumption, the use of so distinctive a term is scarcely for the present advisable. It is true that Mr. Lydekker insists upon the existence somewhere of a pre-silurian gneiss from which the blocks in the silurian slates must have been derived; but it is not certain, however probable, that that rock lay within the Himalayan region at all, and until found it would be better designated by some less specific name. The reason given for preferring the name 'central' rather than archæan (p. 269) is certainly not admissible; it is, that some of the so-called gneiss is now shown to be intrusive. It would be rather subversive of geological principles to regulate the nomenclature of stratified systems according to the igneous rocks that may have invaded them; and it is clear that in this case the ambiguity is not in the words 'central' and 'archæan,'

but in the word 'gneiss,' if we choose to retain it for a rock that is proved to be a foliated granite, as which it should be coloured on the map whenever its origin can be established. Or if the 'central gneiss,' as Mr. Lydekker suggests (p. 270), is only to indicate the lower limit of a general metamorphism as defined on the Bhabeh section, it would form an incongruous member in a scale of formations based upon wholly different conditions.

Mr. Lydekker continues the introduction to his description of the crystalline and metamorphic system with a discussion of Colonel McMahon's papers on the Dhuladhár, remarking that in the last of these "many of the rocks previously alluded to as granitoid gneiss are termed gneissose granite; and it will accordingly be understood that where these terms are employed they must be generally considered as equivalent" (p. 271). It seems to me that this is precisely what we should avoid doing. Compromise, or opportunism, may often be necessary, but in geology at least we can adopt it with our eyes open. The familiar example of chalk and cheese would not adequately represent the confusion here recommended; it would be better illustrated as between blood and bone in biological research, a provisional equivalence which Mr. Lydekker would hardly tolerate. In the ascending scale of differentiation the possibility of mistake has there been removed; but intrinsically among rocks the functional distinction of gneiss and granite is just as radical. Except by survivals of the Wernerian school gneiss is regarded as of sedimentary stratified origin; and even though locally derived by a new birth from the base of the earth's stratified shell, granite is essentially the very reverse of sedimentary. I have no doubt Colonel McMahon would abstain from applying the term gneissose granite without sufficient reason, and meanwhile the term granitoid gneiss must carry its full signification; for it must be possible that a gneiss should reach the last verge of metamorphism without extinction of its original stratified relations; on the other hand, it would be difficult to place a limit on the pseudo-schistose texture an erupted mass may assume under certain conditions.

In subsequent pages Mr. Lydekker gives liberal extracts from Colonel McMahon's papers. They will serve to give his non-professional readers an idea of what is understood by critical observation in geology, but they seem to be introduced as a basis for an imaginary contention (p. 280) in which Colonel McMahon is supposed to deny the existence of the granitoid gneiss even in the Dhuladhár. Seeing that the evidence quoted at top of the next page for the existence of an archæan series of metamorphic rocks in the Himalaya is from Colonel McMahon's observations (Records, Vol. X, p. 204) this is rather perplexing; the conclusion was not made from a thorough study of the ground, but it was formally sound, and it is almost the only positive evidence we have left on this important question, so I am anxious to see how it will stand the test of Mr. Oldham's approaching investigation. It is impossible to admit with Mr. Lydekker (p. 280) that the occurrence of boulders of granitoid rock in the slates of Pángi proves that such a rock was then exposed in Pángi, Chamba, and Kashmir; especially if those boulders were, as he conjectures, due to transport by ice, they may have come from much farther, possibly from the middle Himalayan region to the east.

With the fictitious contention over the archæan gneiss there is involved one on the intricate structural question of faulting *versus* flexure with inversion. This too is peculiarly open to misunderstanding, for more or less of faulting would be inseparable from a folded flexure. Colonel McMahon has not recognised any inverted strata in the Dalhousie section, and so does not yet see the need of the folded flexure. Mr. Lydekker has made out a good case for an inverted series on the outer flank of the Pir Panjál, and would extend it to the Dhuladhár, as these ranges are certainly homologous; and I think that in the main he is right; but here again it would not be supposed from his text that this was the view taken of the Dhuladhár in the first Himalayan work of the Survey (Memoirs, Vol. III, 2, p. 63, 1864).

NORTH-WEST FRONTIER: *Mr. Blanford.*

The recent publication of Mr. Blanford's memoir (Vol. XX, part 2) on his examination of the hills in Northern Baluchistan and South-Eastern Afghanistan during the season 1881-82 brings forward some points that were not available for last year's report. I need hardly say that the memoir is replete with sound observation and lucid exposition, or how much we have to regret that it is the last record of geological field-work in India that we can expect from Mr. Blanford. A slight alteration of the classification of formations adopted in his Sind Memoir is now indicated (p. 46): according to the critical examination of the fossils by Dr. Martin Duncan (Pal. Ind. Ser. XIV) the *Cardita beaumonti* beds are now placed as lowest eocene instead of cretaceous; and the change is also rather in accordance with their petrological characters. Their position below the trap had something to say to their being regarded as cretaceous, and now we have to give a corresponding lift to the trap itself which is presumed to belong to the period of the Deccan trap; this must have been one of great duration, and the eocene basalt of Ranikot would probably belong to its uppermost horizon. The total disappearance of the Gáj and Nari marine beds of Sind in the western highlands as well as northwards is a very interesting observation. The latter feature was a prominent object of Mr. Blanford's investigation, with a view to the correlation of the sub-Himalayan tertiaries, and although the examination was not carried so far northwards as was hoped for, the question is, I think, virtually settled as far as it is likely to be from this quarter, though perhaps not as Mr. Blanford suggests. The correspondence of the Manchhars of Sind with the Siwaliks has been fully recognised, and Mr. Blanford has now traced them continuously along the Bugti and Suleiman hills, where for a considerable distance they overlap all the middle tertiary groups and rest upon the eocene. The marine Gáj and lower Nari do not occur at all in this ground, but a sandstone which Mr. Blanford takes to represent the Nari sandstone re-appears on the flanks of the Suleiman resting on the eocene shales, and he suggests (p. 55) that it may represent the Murree beds of the sub-Himalaya. I hardly think that this will prove correct. The lithological resemblance is not so close as Mr. Blanford supposes; "brown sandstone, rather harder and darker than the Siwalik sandstone," does not at all match the Murree or Dugshai rock, which has a prevailing purple colour and is densely hard. There are rocks above the Murree horizon and below any recognised Siwaliks that would answer much better to the Nari sand-

stone of the Suleiman. But this is the least consideration. The intimate transition of the Murree beds and the eocene is not described as occurring at the base of the Nari in the Suleiman section; there is also a much greater thickness of deposits above the Murree zone in the sub-Himalayan region than above the Nari in the Suleiman. These considerations coalesce with what must, I think, be taken as the probabilities of the case: the exclusion of the sea from the northern ground was a most gradual change and no doubt took effect earliest in the north, where the highest marine and lowest fresh water deposits would thus presumably be older than at any point to the south. It is not unlikely that the whole Sirmur series is eocene. This sort of thing is no doubt awkward for the map maker; geologists must only learn to adapt their scales to the processes of nature.

ASSAM: *Mr. LaTouche.*

At the other end of the Himalayan area, in Assam, Mr. LaTouche was engaged, at the special request of the Public Works Department, in prospecting for coal and iron, where it was pretty certain none would be found, in the upper tertiary rocks forming the hills between Cachar and the Dimapur valley in Assam through which it is proposed to run a line of railway. The result was as expected; but in proceeding to his work Mr. LaTouche traversed some new ground, a note upon which is published in the Records for the year. He was to have taken up during the current season the survey of the coal-field in the Gáro hills, his preliminary examination of which was made at the close of the last season (Records, Vol. XVI, p. 164); but with the permission of the Chief Commissioner he was deputed to accompany the survey party under Lieutenant-Colonel Woodthorpe, R.E., proceeding to explore the Upper Dehing basin. This would be very interesting ground, as it must reach beyond the zone of tertiary rocks fringing the Upper Assam Valley and probably beyond the range of the Arakan-Munipur axis. Unfortunately this plan was interrupted by the Aka raid, the survey party being diverted into that territory, and Mr. LaTouche with it. This is Himalayan ground proper, not far to the west of the Daphla district visited by Colonel Godwin-Austen in 1865, and probably like it in structure.

TINNEVELLY-MADURA: *Mr. Foote.*

The Peninsula Area.—Mr. Foote completed his survey of the coastal region on both sides of Cape Comorin, and the result is now published (Memoirs, Vol. XX, part 1) with a large map. The region is not particularly attractive geologically. One point of general interest has been provisionally suggested by Mr. Foote. The age of the Cuddalore sandstones has been unknown ever since the formation was first described by Mr. H. F. Blanford under this name in 1863 (Memoirs, Vol. IV, part 1); it occurs extensively in the Godavari district as the Rajamundri sandstone, and in Travancore as the Warkilli beds, and at many intermediate points. It is totally severed from the cretaceous deposits of Trichinopoli, but as it had only yielded silicified wood and impure lignite, nothing could be fixed as to its age, and it has passed generally as tertiary. Mr. Foote has now (p. 40) with some probability identified a fossiliferous marine sandstone as belonging to this group. If this observation be upheld, or rather until it is contradicted, the Cuddalore sandstones must rank as post-tertiary or even sub-recent.

In this connection I may mention the recent re-discovery of General Cullen's tertiary limestone near Quilon by Mr. Logan, the Resident in Travancore. In the annual report for 1881 (Records, Vol. XV), I mentioned that Mr. King had failed to find his interesting bed during his rapid survey of the Warkilli deposits (Records, Vol. XV, p. 94). It was certainly not to be found at the place assigned in the published account of General Cullen's observations, and no one at Quilon could put Mr. King on the track of it. Mr. Logan has now sent specimens collected by himself at the spot, known as Purappakkara, about 7 miles north-east of Quilon, a much greater distance than that given in the notes published by Dr. Carter. General Cullen was presumably an Irishman.

TERTIARY LIMESTONE AT QUILON.

By desire of His Excellency the Governor of Madras Mr. Foote at the beginning of the current field season took up the exploration of the ossiferous caves in the Karnul district, mention of which was made in last year's report. Owing to the total want of local information regarding these caves there was much difficulty in finding them, and work was commenced in a cave said to be called Billa Surgam, but which turned out not to be the locality where Newbold had made excavations. This cave was, however, found out in time, and the exploration has now made some progress with fair promise of success. Unfortunately a diversion has arisen in an urgent demand for the examination of the country between Bezvada, Singareni, and Hyderabad, with a view to the possible occurrence of coal and iron deposits, in connection with a new line of railway. No other officer being available it has been necessary to depute Mr. Foote for this work, the cave exploration being for the time suspended.

BILLA SURGAM CAVES.

In March last regular mining exploration of the Umaria coal-field was commenced under Mr. Hughes' direction by opening a shaft of 10 feet in diameter. There being no suitable shelter on the ground the work had to be suspended during the monsoon; but an early start was made at the beginning of the current season, by the close of which it is fully expected a sufficient judgment can be formed of the value of the coal-seam. It is also hoped that the survey of the much larger Sohagpur coal-field will be completed during this field season. Mr. Hughes continues to report favourably of the services rendered by Sub-Assistant Hira Lal.

THE SOUTH REWAH COAL-FIELDS: *Mr. Hughes.*

In connection with the coal-fields of South Rewah, the resources of iron for which the north of the Jubulpur district has long been noted assume much importance. The information regarding the nature and extent of the ores not being as definite as was desirable, Mr. Mallet was deputed to examine the question. His report is published in the Records (Vol. XVI, pt. 2). It shows how exceptionally favourable all the other conditions are for extensive iron manufacture if the coal be found suitable.

KATNI IRON ORES: *Mr. Mallet.*

Dr. King returned from furlough on the 11th of May. Before leaving Madras he was called upon to accompany His Excellency the Governor on his tour through the Cuddapah and Kurnool districts. At the beginning of the current season Dr. King took up work on the coal-fields in eastern Chhattisgarh, commenced some years ago by Mr. Ball. He has been specially directed to select sites for trial

CHHATTISGARH COAL-FIELDS: *Dr. King.*

borings in the Hengir Coal-field in connection with the projected line of railway.

By prolonging the season's work well into the hot weather Mr. Fedden was able to complete his survey of Kattywar. The area is principally occupied by the Deccan trap, of which it was not desirable to attempt a detailed survey throughout, so the work lay principally in the tertiary and post-tertiary deposits of the coastal region, with some secondary rocks on the north-east margin. To prepare his work for publication as well as to give assistance in the museum during Dr. Feistmantel's absence and on account of the Exhibition it has been necessary to retain Mr. Fedden at office during the current field season.

KATTYWAR: *Mr. Fedden.*

After picking up some outliers of the marine cretaceous rocks in Khandesh and Nimar, Mr. Bose extended his survey eastwards to Nimawar to take advantage of the new survey sheets of that ground. The map required to illustrate Mr. Bose's memoir of this large area is rather intricate, so there is some delay in publication. For the current season Mr. Bose has been transferred to the unexplored region of the upper Mahanadi basin, of which detailed maps are now available.

KHANDESH, NIMAR: *Mr. Bose.*

Sub-Assistant Kishen Singh extended his mapping of the Vindhyan lines, east of Bundi. In the middle of the season he was recalled to Bengal, an urgent requisition having been made by the Public Works authorities for a search for limestone in connection with Barakar iron works and the new line of railway to the south-west. Sub-Assistant Kishen Singh brought in numerous specimens of limestone from new localities in the gneissic rocks, but none of them were of better quality or more conveniently placed than that already in use. I would here record the instructive fact that the native assistants are the first to complain of the heat and to propose a retreat from field work.

Publications.—Five parts of the Memoirs were published during the year, completing Volumes XIX, XX, and XXII. The appearance of Volume XXII before Volume XXI has been unavoidable. There were seven memoirs about ready to start and with nearly the same apparent prospects of a finish, and it was necessary to assign a place for each with a view to the lettering of maps and plates; once these were well in hand it was not possible to change. Part 3 of Volume XIX is the catalogue of Indian earthquakes commenced long ago by Dr. Oldham and now edited by Mr. R. D. Oldham with a map of the principal seismic areas. Part 4 is Mr. Oldham's account of his observations in Manipur and the Naga Hills, the publication of which was delayed for the preparation of a map including the recent surveys. Volumes XX and XXII contain the memoirs by Messrs. Blanford, Foote, and Lydekker, of which notice has been given above.

The Records for the year (Vol. XVI) contain 24 articles of various interest with numerous maps and plates.

Of the Palæontologia Indica a full part containing a large section of the Brachiopoda of the Productus-limestone of the Salt-range by Dr. Waagen was issued during the year; also a part on the tertiary Echinoidea of Kach and Kattywar, by Dr. Duncan. Two other parts are on the verge of publication; one by Dr. Duncan on the Fossil Echinoidea of the Kirthar and Nari groups in Sind; and one by Mr. Lydekker on the Siwalik Carnivora.

Museum.—The collections in the museum are in good preservation. Mr. Mallet's descriptive catalogue of the systematic series of minerals was issued in May; also, in December, his Guide to the Economic Mineral Products, giving a very instructive account of each class of substance, its use and distribution, with reference to the specimens in the cases. The foreign and Indian samples are placed separately in the several classes, as are also the samples from the different provinces of India.

Library.—The additions to the library were 1,597 volumes or parts of volumes, 740 by purchase and 857 by donation or exchange. Numerous valuable offers of exchange for the publications of the Survey were received and accepted, with the sanction of Government. I am glad to be able to say that the promise made in last year's report has been fulfilled; the catalogue of the library is now at the press. But for the unflagging exertions of our librarian, Mr. W. R. Bion, this could not have been accomplished, in addition to his already sufficient duties as Registrar; he has devoted many spare hours of holiday time to preparing and arranging the slips for the library catalogue.

Seismometric observations.—With the co-operation of Mr. H. F. Blanford, Meteorological Reporter to Government, some simple seismometric instruments have now been set up at Silchar, Sibsagor, and Shillong, forming a minimum group for the determination of centres of disturbance in the Assam region.

Personnel.—Mr. Hacket was absent on furlough throughout the year; and Dr. Feistmantel went on furlough on the 28th March. Mr. Wynne left India on medical certificate on the 17th March 1880; and after repeated extensions of sick leave he had finally to be invalided, retiring from the service on 11th April 1883. When he joined in November 1862 he had had several years' experience on the geological survey in Ireland. In India some choice fields of work fell to him, such as Cutch (Kach) and the Salt-range, of which he has left well illustrated descriptions in our Memoirs. Mr. Lydekker too has not returned from the special leave taken in February 1882; having obtained extension of leave for 14 months without pay he resigned his appointment under an arrangement that permits of his completing the work he had in hand. He joined the Survey in November 1874, and his short career in India has been a very busy one. As soon as our collections were moved to the new museum and amalgamated with those of the Asiatic Society of Bengal, he undertook the arrangement and description of the extensive series of tertiary vertebrate fossils, large additions to which were made by Mr. Theobald in the Punjab. Mr. Lydekker's description of the Siwalik fauna in the Palæontologia Indica will form an enduring record of his zeal and ability. Two new assistants joined the Survey on the 28th December—Mr. Edward James Jones, A.S.R.M., and Mr. Charles Stewart Middlemiss, A.B. (Cantab). They have gone to be broken-in to camp life; Mr. Jones, with Mr. Hughes in south Rewah; and Mr. Middlemiss, with Mr. Oldham in the Himalaya.

H. B. MEDLICOTT,
Superintendent, Geological Survey of India.

CALCUTTA,
The 22nd January 1884.

List of Societies and other Institutions from which Publications have been received in donation or exchange, for the Library of the Geological Survey of India, during the year 1883.

AMSTERDAM.—Netherlands Colonial Department.
BALLAARAT.—School of Mines.
BASEL.—Natural History Society.
BATAVIA.—Batavian Society of Arts and Sciences.
BELFAST.—Natural History Society.
BERLIN.—German Geological Society.
,, Royal Prussian Academy of Science.
BOLOGNA.—Committee, International Geological Commission.
,, Geological Institute.
,, International Geological Congress.
BOMBAY.—Bombay Branch, Royal Asiatic Society.
BOSTON.—American Academy of Arts and Sciences.
,, Society of Natural History.
BRESLAU.—Silesian Society of Natural History.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Geological Society of Belgium.
,, Royal Academy of Science, Belgium.
,, Royal Geographical Society of Belgium.
,, Royal Malacological Society.
,, Royal Natural History Museum of Belgium.
BUDAPEST.—Geological Institute, Hungary.
BUFFALO.—Society of Natural Sciences.
CAEN.—Linnean Society of Normandy.
CALCUTTA.—Agricultural and Horticultural Society.
,, Asiatic Society of Bengal.
,, Calcutta Exhibition of Indian Arts and Manufactures.
,, Economic Museum.
,, Jeypore Exhibition for Indian Raw Produce, Arts and Manufactures.
,, Meteorological Department, Government of India.
CAMBRIDGE.—Philosophical Society.
CAMBRIDGE, MASS.—Museum of Comparative Zoology.
CASSEL.—Society of Natural History.
CHRISTIANIA.—Editorial Committee, Norwegian North Atlantic Expedition.
COPENHAGEN.—Royal Danish Academy.
DEHRA DUN.—Great Trigonometrical Survey of India.
DIJON.—Academy of Sciences.
DRESDEN.—Isis Society.
DUBLIN.—Royal Geological Society of Ireland.
,, Royal Irish Academy.

EDINBURGH.—Royal Scottish Society of Arts.
,, Royal Society of Edinburgh.
GENEVA.—Physical and Natural History Society.
GLARUS.—Swiss Society of Natural Science.
GLASGOW.—Glasgow University.
,, Philosophical Society.
GÖTTINGEN—Royal Society.
HALLE.—Leopoldino Academy.
,, Natural History Society.
HARRISBURG.—Geological Survey of Pennsylvania.
HOBART TOWN.—Royal Society of Tasmania.
KÖNIGSBURG.—Physikalisch-ökonomischen Gesellschaft.
LAUSANNE.—Vaudois Society of Natural Science.
LIVERPOOL.—Geological Society.
LONDON.—Geological Society.
,, Iron and Steel Institute.
,, Journal of Science.
,, Linnean Society.
,, Royal Asiatic Society of Great Britain and Ireland.
,, Royal Geographical Society.
,, Royal Institute of Great Britain.
,, Royal Society.
,, Society of Arts.
,, Zoological Society.
LYONS.—Association of Natural Sciences.
,, Museum of Natural Science.
MADRAS —Literary Society.
MADRID.—Geographical Society.
MANCHESTER.—Geological Society.
MELBOURNE.—Mining Department, Victoria.
,, Royal Society of Victoria.
MILAN.—Italian Society of Natural Science.
MINNEAPOLIS.—Minnesota Academy of Natural Sciences.
MOSCOW.—Imperial Society of Naturalists.
MUNICH.—Royal Bavarian Academy.
NEUCHATEL.—Society of Natural Sciences.
[NEW]CASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—American Journal of Science.
NEW ZEALAND.—Museum of New Zealand.
PARIS.—Geological Society of France.
,, Mining Department.
PHILADELPHIA.—Academy of Natural Sciences.
,, American Philosophical Society.
,, Franklin Institute.
PISA.—Society of Natural Sciences, Tuscany.

PLYMOUTH.—Royal Geological Society of Cornwall.
ROME.—R. Accademia dei Lincei.
" Royal Geological Commission of Italy.
ROORKEE.—Thomason College of Civil Engineering.
ST. PETERSBURG.—Geological Commission of the Russian Empire.
" Imperial Academy of Sciences.
SALEM, MASS.—American Association for the Advancement of Science.
" Peabody Academy of Science.
SIMLA.—Quartermaster General's Department, India.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
STOCKHOLM.—Geological Survey of Sweden.
SYDNEY.—Australian Museum.
" Royal Society of New South Wales.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
VIENNA.—Imperial Academy of Sciences.
" Imperial Geological Institute.
WASHINGTON.—Department of Agriculture.
" Smithsonian Institute.
" United States Geographical Survey west of the 100th Meridian.
" United States Geological Survey.
WELLINGTON.—New Zealand Institute.
YOKOHAMA.—German Naturalists' Society.
YORK.—Yorkshire Philosophical Society.

The Governments of Bombay, Madras, North-Western Provinces and Oudh, and the Punjab.
Chief Commissioners of Assam, British Burma, and Central Provinces.
The Commissioner of Northern India, Salt Revenue.
The Resident at Hyderabad.
The Comptroller General.
The Surveyor General of India.
The Superintendent of Government Farms, Madras.
Departments of Revenue and Agriculture, Foreign, and Home.

Considerations on the Smooth-water Anchorages, *or* Mud Banks *of* Narrakal *and* Alleppy *on the* Travancore Coast. *By* W. KING, B.A., D.Sc., *Deputy Superintendent, Geological Survey of India.* (*With a map.*)

From time immemorial two anchorages on the west coast of Southern India have been known to mariners as presenting the marvellous feature of being perfectly quiet and smooth, while the sea outside may be tumbling in before the gales of the south-west monsoon. The bottom, or ground, of these anchorages is also peculiar in being a very fine, soft, unctuous mud, which has over and over

again been supposed to act as a barrier against which the force of the waves was expended.

In these quiet roads, ships are not only able to ride safely, but, so it is said, can sometimes take in water alongside, the sea beneath them being so diluted with fresh water from inland sources at this particular season. Not only is there this wonderful quietness of the sea; but at times on one of the banks the smooth surface may be broken by burstings up, or huge bubbles—"cones" as they have been called—of water or mud from the sea bed, and even roots and trunks are reported to have floated up with these ebullitions. Yet, again, the banks of mud are not fixed in position, but move along the coast within ranges of some miles in extent; or one of them may remain comparatively stationary, while the other may move; and these movements do not take place year by year as having a relation to the monsoon periods, but continue over many years.

Unfortunately no continued series of systematic observations has ever been made with reference to these phenomena, so that no satisfactory conclusions could be formed as to their origin or causes. From time to time, however, observations have been made, and suggestions offered, in explanation of them; some of which when looked into are very plausible, and may indeed be the right ones. There is no doubt, however, that certain of these observations require corroboration; and with a view to this, the present paper—practically a compilation of previous knowledge—is now put forward.

Within the last few years these banks have once more attracted attention: first in a commission of enquiry into the harbours on the west coast in 1881, conducted by the then Superintending Engineer (Colonel R. H. Sankey, R.E., C.B.) for Madras; and next by Mr. Logan, the Acting Resident of Travancore, in his Administration Report for 1881-82. The Harbour Commission was carried on early in the year, when the conditions of the weather were altogether unfavourable to any exhibition of the features of these anchorages, the sea being generally quite calm; but I was enabled then to obtain some specimens of the mud. An analysis of this showed its oily constitution, and thus some of the obscurity surrounding the action of the mud was cleared off. Subsequently Mr. Logan's evident great interest in the matter led to the writing of a paper by Mr. Rohde, the Commercial Agent of Alleppy, which throws greater light on other features of the phenomena.

By all accounts there are other but quite insignificant patches of smooth water and mud bank at various points along the Travancore and Malabar coasts, but those best marked and most generally known are near Cochin and Alleppy. There is no well-defined situation for either of these banks on account of their movements to the North or South. That near Cochin or the Narrakal bank may be said to lie between Cochin and the Cranganore river, 11¾ miles to the north; or the range over which it has been observed during the last 200 years is about 11¾ miles: it does not appear to have ever passed south of the northern spit of the opening of the great backwater at Cochin; and for many years its position has been about the middle of the range, between the villages of Nairumbalum and Veearrakull (Narrakal). The other bank, 40 miles or so to the south of this, ranges from a mile or two north of Aulopolay (Alleppy) to Poracaud, a distance

of 12 or 15 miles: it is now, and has been for several years, at the southern end of this range, and indeed goes often by the name of the Poracaud mud bank.

The term 'Mud Bay' has been applied by writers and explorers to both anchorages, though there is no bay feature about either of them now. An explanation of the use of the word 'bay' will be found in one of the extracts given further on.

The mud banks are situated close along the beach, but extend out to seaward for some miles, presenting a more or less semi-circular or flat crescentic convex edge to the long rollers and tumbling waves of monsoony weather. Thus it is quite easy for boats or small canoes to put off from the shore.

Ordinarily, during the non-prevalence of the monsoon, the sea is tolerably smooth, only rolling on the shore with more or less of a surf; and then these patches are only to be distinguished by the soundings of mud below them. Even when the monsoon bursts, it is said that they are not always distinguishable at once, but generally only after a few days or so when the whole sea line has been affected and the mud at these particular places stirred up. After this the muddy waters will calm down and so remain for the rest of the monsoon.

The mud itself is essentially characteristic, and, as far as my limited experience goes of muds along this coast, unique. It is, when brought up, of a decided dark-green colour, slightly tinged with brown; exceedingly fine in texture, only slightly gritty at times from fragments of comminuted shells; very soft and oily feeling, altogether just like a very fine soft ointment or pomatum. After a time it dries and hardens, loses its oily feel, and becomes harsh like an ordinary mud. It is easily stirred up on the bank, being in its upper part of great liquidity, the lead or the boat pole sinking into it from 3 to 6 feet: below, it is more compact, and still deeper forms a good holding ground for anchors. It has always been described as havgni a slimy or oily consistency, but that it actually contained oil has, I believe, only been surmised by a few observers; indeed, as will be seen further on, one scientific observer rather scouts the idea. There is no doubt, however, that it does contain oil in appreciable quantity, as ascertained by analyses of the specimens obtained in January 1881, and sent up then to the Survey laboratory in Calcutta.

The specimens sent up were as follows :—

1017. Mud, off the Cochin river mouth, 4 fathoms.

1018. Mud, from the Narrakal bank, 4 miles north, close in shore.

1020. Mud, from Narrakal bank, off pier head, 2 fathoms.

1019. Mud, from Poracaud bank, 7 miles south of Alleppy, 1 mile from shore, $2\frac{1}{2}$ fathoms.

1021. Mud from Poracaud bank, 7 miles south of Alleppy, $2\frac{1}{2}$ miles from shore, 4 fathoms.

My colleague, Mr. F. R. Mallet, who made the assays, writes :—

"All gave off, when subjected to distillation, some brownish-yellow oily matter lighter than water, and looking not unlike petroleum. No. 1019 gave off the largest quantity, 1017 nearly as much, 1021 a smaller amount, 1020 very little, and 1018 almost none: 1019 and 1021 were

digested with ether, which extracted a small quantity of brownish-yellow greasy matter from them; the other samples were not tried in this way.

"The quantities of mud sent were too small to allow of the oily matter (which in the case of 019 only amounted to a drop or two) being subjected to examination."

A further point about the constitution of these muds is that they contain a considerable quantity of forameniferal and infusorial remains, which were described by the late Captain Jesse Mitchell, Superintendent of the Government Central Museum, Madras.[1] The foramenifera are referred to the genus Rotalina (D'Orbigny); and the Diatomaceæ are summarized as containing in all 62 species belonging to 30 genera. He also says that the mud first received had a brown colour; but that a second supply, which was quite wet, had a somewhat greenish tinge, the colour depending on the quantity of water present. Some, which had been exposed for several days to the sun, became almost white.

I will now proceed to lay before the reader the further published information regarding these phenomena, and the theories as to their origin.

Alleppy-Poracaud bank.—The earliest account dates as far back as 1678 to 1723, in an extract from Hamilton's account of the East Indies in Pinkerton's Collection of Voyages and Travels,[2] which is given in the Administration Report for Travancore, 1860.

"Mud Bay is a place that, I believe, few can parallel in the world: it lies on the shore of St. Andrea, about half a league out in the sea, and is open to the wide ocean, and has neither Island nor bank to break off the force of the billows which come rolling with great violence on all parts of the Coast in the South West monsoon, but on the bank of mud, lose themselves in a moment, and ships lie on it, as secure as in the best harbour without motion or disturbance. It reaches about a mile long shore, and has shifted from the northward in 30 years about three miles.

"A MS. note has the following remark:—This singular accumulation of mud still exists, and still affords the same convenience for anchorage in the worst weather. The present account was published in 1723 and now in 1825. The mud bank has shifted from St. Andrea in N. Lat. 90° 40′ to Poonaganot in N. Lat. 90° 25′, being 15 miles in 102 years."

Mr. Maltby (then Resident) adds:

The mud bank now (1860) is in latitude 90° 28′ 30″.

The next account I can find is of much later date, in "Notes of an excursion along the Travancore Backwater," by Captain Heber Drury, 45th N. I., dated 1858.

"Alleppey,[3] Aulopolay, or Alapushe, as it has been variously named, is the present commercial port of Travancore, and the principal depôt for Salt, Cardamoms, Pepper, Teak-wood, and other products of the country. It is reached by a canal leading from the backwater nearly due west, the length being about 3 miles." * * * * * * * * * * * * *

"Important as Alleppey is to the Travancore Government as a commercial depôt, from the facility of an inland water communication, which enables the forest products to be brought to the very doors of the godowns established for their reception, yet undoubtedly its greatest advantage as an emporium arises from the singular natural breakwater formed in the open roadstead, and which consists of a long and wide bank of mud, the effect of which is so completely to break the force of the houses (*sic*), that large vessels in the stormiest weather can securely anchor in the open roads,

[1] Jour., Madras, Lit. and Sec., XXII, N. S. 6., p. 264, *et seq.*

[2] See, XIII, Public Works of Travancore. Proceedings of the Madras Government, 1861. Published also in the Madras Jour., Lit. and Sci., XXII, N. S. 6., p. 127, *et seq.*

[3] Madras Jour., Lit. and Sci., XIX, N. S. 3, p. 217, *et seq.*

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Mr. Crawford, the then Commercial Agent at Alleppy, thus reports to the Resident of Travancore—date, 20th June 1860[1]:—

"Lieut Taylor attributes smoothness of the water to the soft mud at the bottom, which when 'stired up by a heavy swell from seaward the activity of the waves is so deadened as to render the shore line free from surf.' I regret never having met Lieutenant Taylor.

"A number of years ago, I brought to the notice of General Cullen, that the perfect smoothness of the water in the roads and at the beach at Alleppey, was attributable, not to the softness of the mud at the bottom, so much as the fact of the existence of a subterranean passage or stream, or a succession of them, which communicating with some of the rivers inland and backwater become more active after heavy rains, particularly at the commencement of the monsoon, than in the dry season, in carrying off the accumulating water, and with it vast quantities of soft mud. General Cullen, the Resident, sent a quantity of piping and boring apparatus in order to test the existence or otherwise of what I had urged. Accordingly, I sunk pipes about 700 yards east from the beach and at between 50 and 60 feet depth: and after going through a crust of chocolate-colored sandstone, or a conglomerate mixture of that and lignite, the shafting ran suddenly down to 80 feet; fortunately it had been attached to a piece of chain, or it would have been lost altogether. Several buckets from this depth were brought up, which corresponded in every respect with that thrown up by the bubbles as they burst at the beach, which I shall here try to describe as accurately as I can. Due west of the Flagstaff and for several miles south, but not north of that, the beach will after or during these rains suddenly subside, leaving a long tract of fissure varying from 40 to 100 or 120 yards in length; the subsidence is not so quick at first, but when the cone of mud once gets above the water the fall is as much as 5 feet in some instances, when the cone bursts, throwing up immense quantities of soft soapy mud, and blue mud of considerable consistence in the form of boulders, with fresh water, debris of vegetable matter, decayed, and in some instances green and fresh. These bubbles are not confined to the seaboard, but are, I am inclined to think, both more active and numerous in the bed of the roads with the Flagstaff bearing from E.-N.-E. to the South, until it bears N.-E. by N., or even South of that. About five years ago for about 4 miles down the coast and from the beach out to sea for a mile and a half, the sea was nothing but *liquid* mud, the fish died, and as these cones reared their heads above the surrounding mud, they would occasionally turn over a dead Porpoise[2] and numerous other fish: the boatmen had considerable difficulty in urging their canoes through this to get outside of it; the beach and roads presented then a singular appearance,—nothing to be seen but these miniature volcanoes, some silent, others active, perfect stillness of all around the ships in the roads as if in some dock, with a heavy sea breaking at 7 fathoms outside.

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"This anchorage known to the pioneers of commerce as Mud Bay is only apparent in the S. W. monsoon, and in 1849 its southern limit was ¼ mile N. of Alleppy, since which date it has steadily shifted to the South, and for the last 3 years has decreased in area each monsoon. The original theory seems to have been that the bank travelled year by year southwards and then suddenly resumed its original place, but from the various observations taken, this seems to be an error, and from the notes I have made during my 13 years residence on the Malabar Coast, I believe that Mr. Crawford, the former Commercial Agent and Master Attendant of Alleppy, and who, in addition to 30 years' residence in Alleppy, had previous nautical experience of the coast, was correct in his conclusion that the bank of mud is created by the hydraulic pressure caused by the level of the vast backwater being, in the S. W. monsoon, some 4 feet higher than the sea. It has been proved by boring that although Alleppy appears to be one vast sand tract it has at a depth of 60 feet * a *soft mud foundation*, and both Mr. Crawford and I have seen mud volcanoes bursting up in the sea during the rainy season. Those that I have witnessed only appeared as if

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a barrel of oil had suddenly been started below the surface, but Mr. Crawford has seen some burst and throw up roots and trunks of trees, and it would appear that the mud bank thus formed is gradually carried down the coast by the littoral currents, and after a certain distance has been travelled, gradually wastes away, and that in place of this bank returning to its original position it is a fresh mud bank that is thrown up at certain periods in the vicinity of Alleppy, which, it should be noted, has the narrowest strip of land between the backwater and the sea. The theory that the mud bank is immediately connected with and due to the height of the backwater being above the sea was, I think, conclusively proved this monsoon, as at the height of the floods, when the canals were 6 feet above ordinary level, the area of the smooth water off Alleppy was so great that it was only by means of a good telescope and standing 20 feet above sea-level that I could see the breakers and heavy rollers beyond the half circle of smooth water. This flood was on the 13th June and was followed by a rapid fall, and the half circle of smooth water of the sea beach contracted as the waters fell. The floods again rose inland, and the smooth water circle expanded in proportion.

This may explain the Alleppy bank, but Narrakal is fixed. I think, however, he is right.

This is very good evidence.

"The mud itself is of a peculiar character and so soft that a light lead (4 lbs) put over the end of a pier apparently shows 2 fathoms of water, but on drawing up the line, 6 feet is found to be water and 6 feet soft oily mud.

"There are other points which, although I do not profess to sufficient scientific knowledge to show the connection between, with the mud bank, I think should be noted, as this natural smooth water anchorage has been a source of much discussion in scientific circles, and I believe that any notes given of the formation of the land must be of interest.

"I cannot give dates as I have no records, but it is certain that the coast from about north of Calicut to south of Quilon was once well above the level of the sea, and was after a long period totally submerged and then again was thrown up by volcanic action and has again been partially covered by sea. I state this because in cutting the Warkilli tunnel, trees were found, and also shells have been found on the coast which are known to belong to a class of shell-fish that only live in very deep water. Remnants of a fort at Poracaud were visible 30 years ago, and at Calicut and Vypeen massive buildings are now in the sea.

"Secondly, I should note that deep pot-holes exist in the big lake East of Alleppy of from 20 to 70 feet in depth, which, seeing that lake is for the most part only a few feet deep, is a curious circumstance and would tend to strengthen the belief that I have heard expressed, that subterranean rivers connect the backwater with the sea.

"The area of the lake to which I refer is nearly 100 square miles, and its nearest point to the sea, 3 miles. With a rise of 4 feet, or as occurred in the floods of 1882, of 6 feet, it can be easily believed that the enormous pressure thus caused would force relief ways for itself below the coast line through soft mud easier than through ground which is densely covered with cocoanut trees, the fibrous roots of which bind the ground into a solid mass.

"A similar mud bank exists off Narrakal, and I have often heard it put forward as an argument that mud banks on this coast do not shift, but I think the steadiness of the bank off Narrakal is due to the enormous body of water which pours out 6 miles south from the Cochin harbour and which scour throws up sand-banks which probably tend to prevent the shifting that would otherwise take place.

I would rather say the sand-banks at mouth of Cranganore river prevent the littoral current—N. to S.—from carrying it away.
W. L.

"Other smaller mud banks occur at different places, but are of too small an area to be available for any shipping business, but they all show a progressive tendency southwards."

Narrakal, or Cochin, Bank.—The only information I can find concerning this bank is from two papers in the Madras Journal of Literature and Science,[1] by Dr. Day and Captain Mitchell.

[1] Vol. XXII., N. S. 6, pp. 260 and 264,—1861; "Narrikal or Cochin Mud Bank." By Francis Day, Civil Surgeon, Cochin; and "The Mud Bank at Narrikal, near Cochin; its composition, as exhibited by the microscope." By Lieutenant J. Mitchell.

In the first, the following extract is given from Stavorinus, the Dutch Navigator, who so far back as 1777 wrote :—

"Coast is safe and clear everywhere along the Company's establishment, except at the mouth of the river of Cranganoor, where there is a reef at the north side which stretches out to the sea, about three-quarters of a league; it is called the reef of Aycotia by our Navigators; before Coylang (Quilon) there is a similar one but which does not extend half so far out. South of the above-mentioned mouth of the river of Cranganoor, there is a bay, formed by mud banks: likewise one not far from Porca, and another south of Cochin: the banks forming which extend full a league out to sea, and into which vessels may run with safety during the bad monsoon, and may lie in twenty and less feet of water, almost without anchors or cables, in perfect security against the heavy seas, which then roll in upon this lee-shore, as they break their force upon the soft mud banks, and within them nothing but a slight motion is perceived."

Dr. Day continues :—

"In Horsburgh's East Indian Directory, fifth edition 1841, page 512, it is stated under the head of Cranganoor Fort—'From the south point (of Aycotia or Cranganoor river) a mud bank with 3 fathoms on it, projects out near two miles to seaward.'

"From the foregoing it appears that a bay protected by mud banks existed between the mouth of the Cranganoor river towards Cochin in 1777 and then appears to have been well known. At present, the same protected spot exists, but it is no longer a bay, and for the following reason. Though the northern projection of the coast at the mouth of the Cranganoor river, forming the northern extremity of the 'mud bay,' is still present, the southern projection, or that between Narrikal and the mouth of the Cochin river, is gone, having in fact been covered by the sea (at this place a church stood, which is now submerged): had it not been so, a 'mud bay' would still be present. It is curious that this law of encroachments of the sea is now the rule on the Western Coast, because tradition [1] and an examination of the geology of the country both lead to the conclusion that the sea formerly washed up to the Western Ghâuts; thus Malabar has been literally raised from the sea.

"During the south-west monsoon, the rivers on the Western Coast swell to a great extent, and become loaded with alluvial deposits. Should any obstruction occur at their outlets, deposits sometimes take place, as at the Cranganoor and Quilon rivers, where mud banks have been so formed. Whether the impediment to the alluvial deposit being carried out to sea is merely owing to the action of the S. W. monsoon causing a great impetus to the waves as they meet the river at its exit, or whether other causes also obtain, must be questioned. In forming the Narrikal mud bank, a reef of rocks, the Aycotia reef, at the mouth of the Cranganoor river, appears to have prevented the S. W. monsoon from causing a divergence of the river's mouth to the northward (as invariably takes place on the western coast unless that bank is protected); this reef (Aycotia) has probably assisted in the formation of the Narrikal, or, more properly speaking, the Cranganoor mud banks.

"The whole of the long islands, between the backwater and the sea, are evidently merely alluvial deposits, brought down by the various rivers in their course from the Western Ghâuts. The direction of these mud banks being the same as the long islands and the character of the soil being similar, demonstrates the causes of their origin to be probably identical. In short, the mud banks are alluvial matter, brought down by the rivers and deposited in the sea where it meets the force of the S. W. monsoon.[2]

"Though *Narrikal* owing to its being the nearest place to Cochin is mentioned, the density of the water is greater proceeding towards the Cranganoor river. It becomes very thick and black, and large pieces of flat hard mud begin to be perceived lying on the shore, about one mile

[1] "In a MSS. account of Malabar, by Hernan Lopez de Castaneda, in 1525, it is said that little more than 2,300 years ago the sea came up to the Western Ghâuts."—(Note by Dr. Day.)

[2] "During the S. W. monsoon, the sea for several miles beyond the entrance of the larger rivers is no longer salt."—(Note by Dr. Day.)

north of Narrikal, having been thrown up by the sea. Passing on towards Cranganoor, a large bank of the same substance exists, evidently brought down by the river, and this is one source from which the mud bay receives a fresh supply."

* * * * * * * * * * "No gases arise from the water, nor oily substance (as has been suggested) floats upon it. It is simply the action of the sea which prevents the subsidence of the mud, for as soon as placed in a still vessel it sinks. The shore is sandy, but amongst the sand alluvial deposit exists. The smoothness of the sea is well described by Stavorinus."

* * * * * "The mud has an unctuous sticky feeling, and is not gritty unless mixed with sand. It is of a very dark greenish colour, has but a slight odour and subsides in water.—Cochin, 5th September 1861."

I have already referred to the organisms described in Captain Mitchell's paper, but he thus writes of the banks and the mud :—

"Captain Castor reports the existence of an extensive mud flat, which, commencing about half a mile south of the village of Narrikal, extends to the north for about four miles. Within this space, in the height of the S. W. Monsoon, he found the sea without a ripple! But the greatest stillness of the sea and the total absence of surf from the beach prevailed between a village named Narambolum and Narrikal, a distance of about one and a half miles ;—at this point Captain Castor was always able to embark from the beach in a small canoe.

"The mud appeared to be exceedingly soft and permitted a 7-lb. lead to penetrate it to the depth of three feet in some parts where there was a superstratum of from six to ten feet of water. Beyond the depth of sixteen feet the bottom attains greater consistence and appears good holding ground. Three miles and a half from the shore the depth was five and a half fathoms and gradually shoaled towards the shore. We are left to conclude that the bank extends to that distance from the shore, but this is not distinctly stated in the published account.

"The small quantity sent to me was damp, and appeared very firm and tenacious; it had, however, been somewhat compressed by the waterproof wrapper in which it was packed. To ascertain if it contained any minute shells a portion was placed in water, but it did not break up readily, and as I wished to avoid any violence that would destroy such delicate structures, I allowed it to soak for twenty-four hours. On shaking it up at the expiration of that time I found that at least half of it could not be separated in that way. I therefore pressed it gently with a glass rod; it resisted the pressure, much in the way that a stiff piece of jelly would do, exhibiting considerable elasticity, as well as tenacity, and it is doubtless these properties that enable it to break the force of the waves:—acting like an immense spring, it yields to their pressure, but in the encounter the water loses its force and becomes quiescent, while the mud gently expanding again is ready for a fresh encounter."

I will now conclude this descriptive portion of my paper with a short geographical sketch of the country exhibiting these phenomena,—that is, from the Cranganore river southwards to Quilon. This range of coast is about 92 miles long: it is tolerably straight—without an indentation giving at all the form of a bay—except at the extreme ends, where, at Cranganore, there is the long southerly trending spit of the northern side of the river's mouth, by all accounts, for I have not visited it, a reef perhaps of laterite or lateritoid rock; and again at Quilon, where a sort of bay is formed by another great reef of laterite or lateritoid rock belonging to the Cuddalore Sandstones of the Survey classification, or the Warkilli beds of local geology. Much less is there any indication of a bay near Alleppy. The fact is, notwithstanding the argument of Dr. Day in the extracts given above, the term "Mud Bay," which has been applied to both places, may perhaps have been adopted for an imaginary bay of smooth water enclosed within the semi-circle of breakers outside. There is no doubt that a portion of the

land near the Cochin end of the Narrakal bank was submerged, the church which stood on it having been known to men now living; but there is, I believe, no knowledge of this land having had the form of a projection like the southern arm of a bay. Be this as it may, the present shore line is a straight one from the Cranganore spit to the Quilon or Tungumshery reefs; and it is low-lying or only a few feet above the level of the sea, and made up of alluvial deposits and sand. Inland from it, the same low-lying deposits, broken by backwaters, extend eastwards for several miles forming the lowest portion of the low country proper of Travancore and Cochin. Then the ground rises, sometimes suddenly, to a low terrace, now much cut up and broken by denudation, which forms the rest of the low country below the elevated mountain land or backbone of this part of Southern India. The low country—that is, alluvial flats and inner low terrace—seldom attains a greater width than 30 miles.

The long stretch of alluvial deposits bordering the sea is broken by several backwaters or lagoons, the largest of which is that extending northwards from the parallel of Alleppy to, and communicating with, the backwater of Cochin. The Alleppy backwater is very wide at its southern end, 8 or 9 miles, but it is not directly behind Alleppy, much less behind the Alleppy-Poracaud mud bank; though the principal rivers entering it flow northwards behind the range of this mud bank. There is no visible communication between the Alleppy backwater and the sea; there being no river mouth of the least importance all along this coast, except at the Cochin backwater, and at Cranganore. The rivers of the country behind Alleppy merely flow into the Alleppy backwater, and, for all that can be seen to the contrary, its waters flow out at the Cochin mouth.

To all appearance, the flat lands of the coast are entirely recent alluvial deposits; consisting of layers of sand and mud overgrown with vegetation, and no doubt held together by the roots of this vegetation. The water of the lagoons is more or less brackish and unfit for drinking; but shallow wells sunk in the narrow coast tracts between lagoon and sea give fresh water. It is not, however, certain—although it is most probable—that other deposits, besides the merely recent alluvial ones, exist along this coast; for at the Quilon end there is every reason to expect that the Cuddalore sandstones (laterite) are underlaid by a peculiar set of clays and muds with seams of lignite and other vegetable matter, like those exhibited further down the coast at the base of the Warkilli cliffs.[1] It is true that the dip of the Warkilli clays and lignite is to the northward, and that they must, or ought—provided no disturbance has taken place—to lie deep under the Tungumshery laterite; but this dip is very low, and a rise of these strata again further to the north would not be unusual. Certainly the lumps of blue clay, described by Mr. Crawford as being turned up in the "cones" of mud or water off Alleppy, answer to the lumps of clay which have fallen down from the lower part of the Warkilli cliffs: and the lumps of hard mud mentioned by Dr. Day as occurring at Narrakal, which I have also seen myself, have a similar constitution and looked to me as though they had been broken off from outcrops in the Narrikal sea bed. Mr. Crawford also mentions his having passed through a "crust of

[1] See Rec. G. S. I., Vol. XV, pt. 2, p. 93.

chocolate-colored sandstone, or a conglomerate mixture of that and lignite;" which strata answer very well to certain rocks at Warkilli.

The proper alluvial flats do not extend further east from the shore line than 14 or 15 miles; and the further inland alluvial flats of the rivers, which are very distinct and wide, do not extend further east than 20 or 22 miles: thus the absolute head of water which could be obtained in subterranean water-bearing strata would never be very high. Indeed, for all practical purposes, in this connection, the head of water looked for in the surmises of previous observers, can only be that attained by the flooding of the backwaters.

The term "volcanic" has been used occasionally by previous observers, perhaps rather as a descriptive term than as referring to any volcanic action; but the elevation or depression of the land is fully recognized as having taken place within comparatively recent periods. It is, however, a question whether there may not be an intimate connection between some of these earth movements and a line of volcanic action which, though now latent, is apparently indicated by the lie of the Maldive and Laccadive groups of coral islands, and yet further north the "Angrias" and "Direction" banks. At the same time, I do not wish to press this, possibly to some readers far-fetched, volcanic element into the discussion, except in so far as that it may not be lost sight of in future observations. Besides, as will be seen, I do not think the observations made up to this time, or the theories offered in explanation of them meet all the features exhibited by these Travancore mud banks.

On a close review of the information given in the various papers above quoted, it is clear that both banks have practically the same constitution, behave similarly, and have the same accompaniments, with the exception of the violent discharges of mud or oil, which, so far as our knowledge goes, are confined to the Alleppy-Poracaud bank.

In considering first the mud itself of these banks, it is to be remarked that it is full of organic matter, and that it contains a sensible amount of oil, some of which may have been derived from the decomposition of organisms. In all seasons it is easily stirred up, and it never settles down into a uniformly compact deposit, but has an upper stratum in a greater state of liquidity than its lower depths. It occupies particular areas within well-defined ranges of movement; it certainly moves from north to south within these ranges, but there is no surety that it moves back again. This movement continues over periods of years.

Now with regard to the progress southwards ceasing at certain points, as at the northern edge of the Cochin river mouth and at Poracaud. A satisfactory explanation can, I think, be given for Narrakal, in the Cochin river, which always flows out at a great rate, carrying the mud out to sea. We have no such mode of transport evident at Poracaud. The southerly movement must be attributed to littoral currents acting over long periods on tenacious muds, which may really only be evolved in large quantities at intermittent periods. Mr. Rohde's suggestion that the mud bank of Alleppy does not travel northwards again, but becomes dissipated at the southern extremity of its range, is very plausible.

Regarding the water over the mud: it is only known to calm down during the south-west monsoon. There is no observation showing how it may be affected

in stormy weather at other seasons. Still, I was led to understand, when in personal communication with Mr. Crawford[1] in 1881, that the calming of the anchorages does not take place until after the monsoon has commenced, and there has been a stirring up of the sea and mud. The quieting of the waters is intensified according to the amount of rainfall during the monsoon; but even if no rain fall, there is a certain amount of quiescence. The calmness continues throughout the monsoon, apparently without any fresh stirring up of the mud. In one locality at least, the water is subject at times to violent agitation through the bursting up of gigantic bubbles of water, mud, or gas,—it is not quite clear which; and these features also appear to be intensified during heavy rainy weather in the monsoon periods. The water over the banks becomes considerably freshened, even to the extent—as I was told by Mr. Crawford—of being drinkable; also according as the monsoon rains are light or heavy. At such times, also, the water gives off fetid odours, and the fish inhabiting it are killed off in large numbers; but whether owing to the freshening of the sea-water, or the exhibition of poisonous matter and vapour in the water, is not clear: perhaps this destruction of life may be due to both causes.

The old idea of the mud bank acting as an elastic barrier against which the wild seas sank into such marvellous quietude must be given up in part at least, now that we have got the more reasonable soother of troubled waters in the oily constitution of the mud. There is, of course, the difficulty of citing, or indeed the absolute want of, authoritative observation of the action of oil on troubled waters; but tradition and anecdote are undoubtedly in favour of it, while there are the newspaper accounts of the experiment which was tried a year or so ago in the harbour of Peterhead, when a stream of oil was cast upon the heavy seas at the harbour's mouth with such success, that vessels were enabled to run in with comparative ease. Even, while writing the present paper, I have had an opportunity of trying a very simple experiment on one of the Calcutta tanks, while a slight breeze rippled its surface. On throwing in about a wine-glassful of petroleum or earth-oil on the lee side of the tank, the oil spread out rapidly over the water against the breeze; the effect was instantaneous and decided, the sharp ripples being quieted down to longer smooth undulations, while there was a distinct semi-circular edge of the oiled water beyond which the ripples kept up their sharper action. In another place, on the side of the tank past which the breeze was blowing, a handful of the oil was thrown out on the waters. The oil immediately spread itself over the water in a thin film, along the outer edge of which the freshening breeze occasionally combed the wavelets, and within the area of the film the ripples were smoothed down to quiet and long undulations. The effect soon passed off, however, while the film of oil soon lost its sharpness of outline; so that it is evident if any continued quietness is to be kept up in water with oil, the supply of it must be continuous.

In the case of the mud banks, it can easily be conceived how the stirring up of the mud in the beginning of the monsoon should produce temporary calmness;

[1] Mr. Crawford is now living in retirement on the Purmerd hills of Travancore, and it was here I had the pleasure of talking with him about the Alleppy coast, which he knows so intimately for more than thirty years.

but there is considerable difficulty in accounting for the long continuance of quiescence without any fresh stirring up. There is certainly the fact that the upper stratum of mud continues in an extreme state of liquidity or attenuation in the water, and that thus a sort of restlessness and freeing of oil particles may be going on for a long period; but I think we must look to a further supply from hidden sources, which are indicated by the more violent burstings forth of water, or mud, or oil, in the form of "cones."

An observation which would have been of the greatest use in this enquiry is wanting, however, and that is as to the condition of the surface of the water at such times, or, in other words, whether a film of oil exists on it.

The amount of oil derivable from the decomposition of the animal and vegetable matter of the organisms in the mud would be, I am inclined to think, hardly sufficient to account for the features exhibited; hence it is necessary to look to other sources for the oil; and even to a source for the continued supply of the mud itself, which is evidently carried away and distributed by littoral currents.

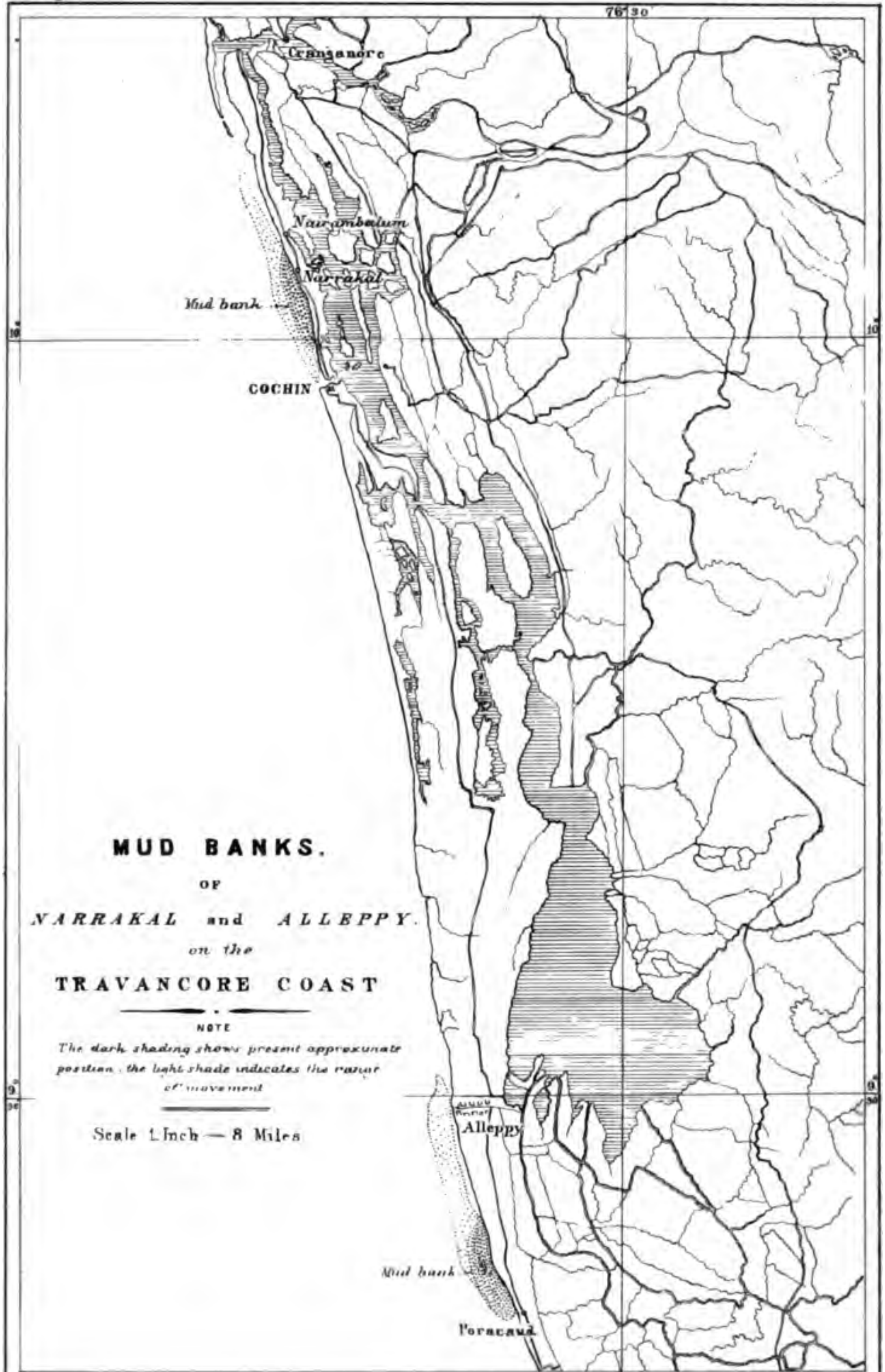
The consensus of observation and opinion certainly leads to the conclusion that there is an underground discharge of water at any rate into the sea from the lagoon and river system behind the Alleppy-Poracaud coast during flood time, the inland waters being at a higher level than the sea. The accounts of such a condition of affairs at the Narrakal bank are, however, not so clear; besides there is the free opening at the Cochin river mouth. Still, underground discharges of lesser intensity may take place; while the lesser pressure likely to be brought to bear on this part of the seaboard may also account for the absence of violent exhibitions like those off Alleppy. This passage of underground waters, as suggested by Mr. Crawford, must then, more particularly during heavy rains, force out large quantities of the mud on which the Alleppy-Poracaud land rests,—as it were like a floating bog, elastic and capable of yielding to pressure, or exerting pressure by its own weight; while a continuous stream, even though very small, of the same oil and mud, may be kept up under the lower pressure of ordinary backwater level. Not only would the underlying sludge and its products be forced out, but it is conceivable that the mud from the backwater should find its way into the same vents, and for a time replace that carried off in the first instance, oil and gases being absorbed in it during that time of replacement.

Excessive floods in the monsoon time only occur at long intervals; and the greater discharges of mud, oil, and gases would then take place; in fact just as they really do at irregular intervals. At such times new banks might be formed; for, during the quieter intermediate season the old ones might be distributed down the coast by littoral currents, and become finally dissipated into the open sea.

Be this as it may, if Mr. Crawford is right, then the source of the mud is evident, and its expulsion from beneath the Alleppy land is explained at once by the hydraulic pressure inland, if it even be only through a head of 6 feet at abnormal periods of flood time.

Speculation of this kind must, however, be kept in abeyance, until further evidence is obtainable as to the character of the sludgy stuff under Alleppy, and of the muds in the backwater, particularly over the deep holes referred to by Mr. Crawford, as also of the mud in the sea outside the banks themselves. A deep

King. Records, XVII



On Stone by S.K. Hossein

boring at Alleppy itself would clear up much obscurity, and it might tell more of the supposed Warkilli beds.

The presence of petroleum has in any case to be accounted for; and, up to this time, there is no observation showing that it occurs in any of the lagoon deposits *per se*. There is at the same time an indication of the possibility of other deposits besides the alluvial ones, in the fact that large lumps of clay or compacter mud, and vegetable remains in a more or less decayed form, are brought to the surface during the prevalence of the violent ebullitions. Mr. Crawford, it must not be forgotten, also mentions his having met with a chocolate-colored sandstone or a conglomerate mixture of that and lignite. Such clays do occur in the Warkilli deposits, and they are associated with lignite beds, in which occur trunks and roots of trees in every stage of decay; some completely carbonized, and others so fresh that they can be cut up and used for making furniture. It may then be that these Warkilli deposits extend northwards under the Alleppy-Poracaud alluvium, and even again at Narrakal, where also fragments of similar clays are thrown up by the sea; and that it is from these deposits as being deeper-seated, older, and lignitiferous that the earth-oil is generated. I am even inclined to look further for an agent in the generation of this oil, like that adduced by Mr. Mallet in his paper on "The mud volcanoes of Rámri and Cheduba,[1]" where he suggests the possibility of oil and gas being generated in lignitiferous strata under the influence of moderate heat arising from a line of volcanic energy; such a line, as I have suggested, possibly lying parallel to the west coast of India.

However, for the present it is best to keep within the sphere of more evident causes shown by the observations which have been made. Thus, the conclusion seems inevitable, that the banks, their smoothening influence, and their position within certain ranges of the coast, may be entirely due to the following causes: First; the discharge of mud from under the lands of Alleppy-Poracaud and Narrakal, this being effected by the percolation or underground passage of lagoon water into the sea. Second; the presence in this mud of oily matter, derived perhaps in part from the decomposition of organisms, but principally from the distillation of oil in subjacent lignitiferous deposits belonging presumably to Warkilli strata. Third; the action of littoral currents which, slowly and through long periods of years, carry the mud down the coast to certain points whence it is dissipated seawards,—by the Quilon river at Narrakal, and at Poracaud because it is there beyond the range of replacement.

Rough notes on Billa Surgam *and other* caves *in the* Kurnool District, *by* R. BRUCE FOOTE, F.G.S., *Deputy Superintendent, Geological Survey of India.*

The following notes embody the results attained up to the present by the examination and partial exploration of Billa Surgam and several other caves in Kurnool district. This work was undertaken at the instance of His Excellency the Right Honourable M. E. Grant Duff, Governor of Madras, who had been

[1] Records, G. S. I., XI, pt. 2, p. 100.

requested by Professor Huxley to procure the further exploration of "Billa Surgam," a place where the late Captain Newbold, F.R.S., had discovered some ossiferous caves. The caves had been practically lost sight of for many years, and their locality was quite unknown to the district officials, both European and native, and to many of the natives even in the near neighbourhood. Captain Newbold's very brief paper on these caves, published in the Journal of the Asiatic Society of Bengal in 1844,[1] was unknown to my colleague, Mr. King, when he surveyed that region, and remained unknown to him (and myself) till after the completion of the work in Kurnool district.

My visit to the neighbourhood of Banaganpalli, which is the nearest place of any importance to the caves, resulted in the re-discovery of Billa Surgam and the fresh discovery of several other caves, one of which is of large size and of great interest geologically, as being a very typical example of the solvent and eroding action of water in limestone on a large scale.

Billa Surgam.

Billa Surgam lies on the south side of a narrow valley opening on the east side of the Yerra Konda or Red Hills, the range of low hills and plateaus forming the western side of the Kurnool basin. Its position is a mile north-north-east of that assigned to it by Newbold, and it lies 3 miles east-south-east of Betumcherru (Baitumcherloo) in the south-eastern corner of Nandyal taluq. It may be described as consisting of three deep but very short "cañons" joined by natural arches. The various caves open into the cañons at different levels. The cañons themselves were once caves of large size, the roofs of which have fallen in, in great part. The ground plan of the place may, for sake of illustration, be compared to a rather distorted figure of 3, the two principal caves being situate on the right side of the upper and lower parts of the figure. The floor of these two caves is considerably above the level of the bed of the stream, which in wet weather flows through the cañons. These two caves are the only ones answering to Newbold's description; both, and especially the larger one, are well furnished with stalactites, and in the latter it is probable that a large quantity of stalagmite will be found under the present floor. In both cases this is formed of a loose blackish-grey soil, largely made up of the dropping of birds, bats, and other animals. The walls of the larger (southern) caves were unfortunately in the occupation of a large colony of wild cliff bees; no fewer than 18 nests, several of immense size, hung within the cave and immediately above the place where excavation should have commenced. The presence of such an element of danger[2] prevented

The two Bone Caves.

[1] Note on the Osseous Breccia and Deposit in the caves of Billa Surgam, lat. 15° 25', long. 78° 15', Southern India. By Captain Newbold.

[2] These cliff bees (*Apis dorsala ?*) are of very unreliable temper, and the natives are much afraid of them. Though often inoffensive, they are sometimes roused and sally forth and attack with great fury any human being or animal they may come across. When working at the Yerra Zari Gabbi (cave), where there was a very large colony of bees, they got excited several times and swarmed down furiously into the mouth of the cave; luckily their great noise gave us warning and we could escape into the dark passages, whither they would not follow. At

me from commencing there at once, and I began with the smaller northern cave inside which there were no bees' nests.

The northern cave.

This northern cave is 70 to 80 feet high and 32 feet wide at its mouth, and decreases in height to 4 feet,[1] 86 feet from the mouth. Its extreme end is formed by a small passage, too narrow and too low to be followed up by an adult. Through this passage and a number of small clefts in the sides the mass of red cave earth filling the bottom of the cave was doubtless washed in. The cave earth as far as excavated showed few pebbles washed in from above, but masses of limestone, often of large size, have fallen from the roof in such numbers as to add very greatly to the labour of excavation in some parts.

The floor of the cave when I first entered it consisted of a loose blackish-grey soil, largely composed of the droppings of blue pigeons and small animals living in the cave. This layer was thickest at the upper or east end of the cave, and thinned out with the slope of the ground westward. Its greatest thickness was about 4 feet, and it contained a few traces of human beings having inhabited the cave; among them were two small chank shells (*Turbinella* or *Mazza*) with the apices of their whorls broken off. These had doubtless been the property of a Gossain or some other religious mendicant. A few bits of broken pottery and one or two bits of charred wood were also found in this surface layer. In several parts of the cave the black soil was found to be full of bones of small animals, birds, lizards, frogs, and of exuviæ of insects and myriapoda which appeared to be derived from the castings of predacious birds. I made a full collection of these for purposes of comparison with the numerous bones of small animals, which, according to Newbold's account, abounded in the red cave earth below.[2] These bones from the upper layer were in no way fossilized,—indeed many of them were quite fresh.

On removing the surface layer a bed of loose loamy red soil was exposed, which had at many points been manifestly disturbed, but to no great depth. Resting on this disturbed surface close to the north wall of the cave at a spot 21 feet westward from the mouth of the small passage which forms the east end of the cave, was a small number of human bones not mineralized but deprived of their animal matter. Among the bones, which were all much broken, are fragments of a skull, teeth, ribs, &c.

Billa Surgam, however, there were no dark passages into which to retreat. After some time I succeeded in getting the nests removed by honey-gatherers, but, despite that, many of the swarms showed no inclination to migrate elsewhere, and remained when I left, fully ten days after the destruction of their combs. Those that left seem to have joined the Yerra Zari Gabbi colony. I had had 26 large nests destroyed there in hope of getting rid of the inhabitants. Many left but returned again, and about a month later I found the colony had increased to 40 nests. It is impossible to smoke them out on such high cliffs, and the only way to get rid of them will be to blow them up with powder.

[1] The heights given above were those taken before the removal of the cave earth was commenced.

[2] The day after I commenced excavating at Billa Surgam, a number of people from the adjacent hamlet of Kotal came over to look at my proceedings, and one of them, a very old man, volunteered the information that he remembered Newbold's visit, and that his excavation was made just a little to the west of mine. He added that Newbold remained about three weeks at Billa Surgam.

From the very small number of bones found here, it is more probable that they were introduced to the cave by some beast of prey than that they were relics of a burial. That these caves afford occasional shelter to wild animals at the present day, is shown by the fact that most of the narrow passages have been built up by the villagers to prevent the beasts from remaining permanently. I found no traces at Billa Surgam of the continued residence of either leopards or hyenas, the most common of the larger carnivora in these parts, though there was no reason, judging from the quiet mode in which the cave earth had been accumulated, why the Album Græcum formed by those animals should not have been preserved, as well as the many minute bones which occur scattered through the cave earth.

Character of the cave earth.

A little below the surface the cave earth was found to become generally clayey, and in parts a very stiff clay. Red is the prevailing colour; and the fallen masses of limestone of all sizes, adverted to above, are found distributed throughout and give the whole a distinctly bedded appearance. No stalagmitic flooring was met with as far as my excavation extended, which was to a depth of 15 feet; but several bones were found in the disturbed upper part of the cave which appear to have been derived from a stalagmitic breccia. I thought at the time these might possibly have been specimens lost accidentally during the progress of Newbold's excavation, but I did not meet with any other indications of exploration. It is, however, quite possible that his excavation was made on the north side of the cave and will be found when further exploration extends thither. My excavation was directed towards taking out systematically the whole mass of cave earth of the southern half down to the rocky floor; and it was carried out down to a depth of 14 feet. I began with the south side as getting the most day-light and being therefore the most advantageous for observing the section.

I am puzzled to know what Newbold meant by a "gypseous rock," unless he referred to some kind not met with in the northern cave.

All the bones that were disinterred during my excavations belong, so far as it was possible to judge from cursory inspection, to living species, but seeing of what great antiquity the caves must be if estimated by the vast amount of denudation the country generally has undergone since their formation, there is no *primâ facie* reason for doubting the existence of remains of greater geological antiquity in the lower parts of the cave deposit.

Prospects of further results.

From the situation of the Billa Surgam caves with regard to the hills adjoining and to the stream flowing through the series of cañons, I consider the prospect of really valuable finds very good, and would strongly urge a continuation of the exploration in an exhaustive manner. The brightness and comparative dryness of the caves must have made them very suitable retreats for savage men as well as for cave-loving animals; while the peculiar character of the material washed in has clearly been very favourable to the preservation of bones. The smaller caves are equally promising with large ones, and there are several rock shelters in other limestone scarps, and especially in one north of the hamlet of Kotal, which should be

explored. It is by no means unreasonable to hope that remains of palæolithic man might occur in them, for I picked up an oval quartzite implement on the talus on the north side of the valley lying between the Billa Surgam ridge and that north of Gorlagootta.

The Yerra Zari Gabbi.

This large and important cave which I had the good fortune to discover opens at foot of a great limestone cliff on the eastern slope of the Yegunta Konda, a small plateau 6 miles north-north-west of Banaganpalli. It takes its name from the great red cliff the "Yerra Zari" in which it is situated and which forms a conspicuous feature on the flank of the plateau, but the mouth of the cave which opens into a very wild and rugged ravine is so hidden by trees that it cannot be seen till one approaches within a few dozen feet. It is quite invisible from the open country below. This cave also was unknown to the people at Banaganpalli, though it lies within the Banaganpalli territory. The cave was formed by the action of a stream rising on the plateau of Paneum quartzite which caps the limestone. The stream was formerly of considerably greater length and volume than at present, and formed a complicated series of chambers and passages which I propose to describe fully with plans and sections in another paper. The floor of the cave is level for a distance of 160 feet, when it divides into two, and the main one begins to rise for a distance of 130 feet till it reaches a kind of platform under a lofty roof which opens into a vertical pot-hole 162 feet in height. Under the pot-hole the main passage bends nearly at a right angle to the west and continues rising greatly for more than 130 feet in distance, when it is blocked by debris. A great talus of angular limestone masses fills this passage and much of the slope below the platform. About the middle of the lower slope the water falling down the pot-hole has formed a considerable mass of stalagmitic breccia. The great side chamber has had its upper end breached and huge rolled masses of quartzite have fallen into it from above. The main stream seems to have flowed through this passage for a considerable period, judging by the rounding and polishing which the great quartzite blocks have undergone. Water still flows through in considerable quantity after heavy rain, but the main stream from the plateau now avoids the cave and flows through the wild ravine to the eastward. An immense amount of debris has been brought into the cave by the streams that have flowed through it. I made three deep sinkings in different parts, one (No. 4)[1] a little distance within the mouth of the cave which reached the rocky bottom at a depth of 27 feet, another (No. 1) in a large side gallery westward of the mouth which failed to reach the bottom at 33 feet, and a third (No. 3) in a higher-lying side gallery which reached the bottom at 26 feet. In the side galleries the surface layer is rather loose black soil with much organic matter, chiefly bat droppings, in it. This showed traces of human tenancy of the cave at several levels. At No. 3 sinking a quantity of antique pottery was unearthed, some of it of excellent quality, but with the exception of one little drinking cup of glazed black ware[2] all was broken. It attracted a good deal of

[1] The numbers in brackets refer to the order in which the sinkings were made.

[2] Of one large chatty I succeeded in finding nearly every piece, so that it can be built up by careful cementing. It shows a very striking style of ornamentation, very different to anything modern.

attention from the natives, who were much struck by its great difference from the pottery now made in that quarter. This pottery was found at a depth of 2½ feet. At a depth of 11 to 12 feet in the same place were traces of a fireplace, and close by lay the drumstick of a common fowl.

At sinking No. 1, broken pottery occurred at a similar depth. The pottery was of the same character as that obtained at No. 3. At the depth of 11 to 12 feet was an old fireplace with many small fragments of charcoal. Some cowdung ash-balls such as used in *āgdans* and several lumps of rather decomposed shale showing strong traces of fire. With the above were various fragments of very coarse pottery.

The loose black surface layer was not found in the main cave at No. 4. There the surface layer consisted of 2½ feet of limestone rubble, under which came the cave earth, which was a brown muddy loam passing into stiff clay of brown or reddish-brown colour, generally full of fragments of decomposing calcareous shale; angular or water-worn fragments of limestone, some washed in, others fallen from the roof, occur at intervals near the surface, but were often numerous at greater depths. At a depth of 3½ feet in the cave earth was a fragment of some marrow bone (apparently ruminant) which showed marks of teeth. Small splinters of bones of good size were not uncommon in the upper part of the cave earth, but all were undeterminable. At a depth of between 12 and 13 feet was a minute but perfectly unmistakable piece of antique bright red pottery, probably the oldest trace of man met with in the cave.

Of three other excavations made in this cave only one was of real importance; of the other two, one was stopped by meeting the bottom of the gallery at a depth of little more than 3 feet, and the other was not brought to a final conclusion. In sinking No. 5, a little below the middle of the high incline leading from the main body of the cave up to the pot-hole, about 12 feet of hard brown or drab stalagmitic breccia were quarried through in a good-sized pit, and a soft bed of drab-coloured breccia reached; but in neither was even the minutest fragment of bone discovered. It should not be concluded that these sinkings are a sufficient test of the contents of this great cave; for though from its darkness and dampness in wet weather it would not be fitted for a dwelling place, it would from its out-of-the-way position form an excellent hiding place. It is more than probable that the pottery found in the different passages had been left there by refugees who had occupied the cave temporarily. The only approximation to a legend in connection with the cave that I succeeded in extracting from the people was a story that it had once served as a place of refuge to the inhabitants of a fort that formerly stood on the edge of the plateau above Yegunta temple, after the fort had been captured during a war.

Both at the Yerra Zari Gabbi and Billa Surgam the walls of the passages are delicately fretted by the action of water trickling down their surface, and the beautiful sections of the limestone thus prepared afford a very strong proof of its unfossiliferous character. If organisms even of very delicate nature existed in it, some few would most assuredly have been worked out by the action of the flowing water which has that effect in so many other places. I examined the cave walls, as far as they were within reach, very carefully, and saw not the faintest indication of any fossil.

Yegunta and other Caves.

A considerable number of other caves of smaller size exist in this limestone istrict, several of which are unquestionably worth further exploration. There re three caves at the Yegunta pagoda in the ravine immediately north of the 'erra Zari Gabbi. Two of these are enlarged rifts along lines of jointing in the mestone; their walls show bunches and fringes of stalactites here and there, but heir floors are concealed by flagging and steps built by devotees who have erected hrines there. Exploration of these caves is of course out of the question at resent. The third cave is a shallow one which is choked at its back with a onsiderable mass of reddish stalagmite-breccia. The very clear and well-dislayed face of this mass of breccia shows thousands of included fragments of shaly imestone; but after careful examination I could not detect a single trace of bone.

In the group of limestone cliffs south of the Yerra Zari Gabbi are several rifts vith stalactites, but too small even if they are ossiferous to contain any large quanity of fossil remains under the piles of angular debris now forming the visible floor.

At the south end of the cliffs what seems to be the top of the arched mouth of considerable cave shows just above a great talus of limestone blocks, the result of a all from the cliff. The presence of a permanent flowing spring emerging from the alus a little distance renders the existence of a cave in the hill above it very robable.

In the group of high limestone cliffs on the south side of the second ravine orth of the south-east corner of the Yegunta plateau is a large and deep recess vith one or more small caves opening near the top of the cliff. These I was unable to reach for want of a long ladder and because of a large colony of bees hat would not be dislodged. From the promising look of the place I think it leserves a very careful examination.

Billam Cave.

Fifteen miles to the south-west-by-south of Banaganpalli there is a cave which was described to me by an intelligent native as of some size and interesting as forming the source of a fair-sized erennial stream. This cave is near the village of Billam (Bollum of sheet 76).

Caves near Gorlagootla.

To return to the neighbourhood of Billa Surgam. On the south side of the great cave ridge and about half a mile due south of it is a small one exposed by a slip of the hill side. The cave s entered by a very steep climb down a rift to a depth of about 30 feet. At the ottom the true floor is hidden by debris which also fills up a passage running vestward so much that it cannot be followed even by crawling on all-fours for nore than three or four yards; but the Gorlagootla people say it joins the Billa Surgam caves. The place had been recently inhabited by a leopard. Very little talactitic matter was seen encrusting the walls. This cave is not easy to find, as ts mouth does not show till one is within three or four yards of it. It opens on o a small terrace 20 to 30 feet long, and occupied by two small but thick trees. The terrace lies about half way up the grassy slope of the ridge and faces eastward.

I was told of two other caves of moderate size to the westward of Gorlagootla, but was unable to visit either from pressure of work at Billa Surgam. One of them was said to occur in the valley of Gorlagootla stream, and will robably be found in connection with a very fine group of limestone cliffs stand-

ing on the north side of the stream. The other, of which the locality was pointed out to me, is situate in a picturesque ravine which one passes on the left-hand side when crossing the small ghat which leads from Gorlagootla to Betum-cherru.

Lastly, I heard of a cave near Buganpilly, 3 miles north-east of Betum-cherru, but could gather no reliable information about it.

From the rather barren character of the soil formed by decomposition of the quartzites and limestones of this region, it is pretty certain that even the virgin forest which once covered the Yerra Konda was by no means impenetrable, and this renders it the more probable that its glades and recesses were familiar to the Palæolithic stone folk, very numerous traces of whom in the shape of quartz-ite implements were found by Mr. King and myself in 1865 near Roodrar only 30 miles to the east-south-east.

Notes on the Geology of the Chuári *and* Sihunta *parganahs of* Chamba, *by* COLONEL C. A. MCMAHON, F.G.S.

Official duties having required me to visit Chuári and Sihunta, the opportunity presented itself of gaining some information regarding the geology of that part of Chamba; though, my leisure being necessarily limited, I was not able to devote as much time as I could have wished to a detailed examination of the rocks.

As Chuári itself has been described in my paper on "The Geology of Dalhousie,"[1] the following pages will deal with the section between Chuári and Sihunta and the neighbourhood of the latter village.

The first fact to be noted is the disappearance of the outer band of gneissose granite,[2] which is typically developed about a mile south of Chuári. I saw no trace of it on the road to Sihunta, though the road crosses all the rock series from the silurians to the siwaliks, nor in the course of the numerous traverses I made to the north and north-east of Sihunta. The mica schists which, in the Dalhousie area, occur next the gneissose granite at the base, or somewhere towards the bottom of the silurian series, are typically developed in this section, but the gneissose granite is absent. The dip of the slates on the Sihunta road is N.-E. 11° N.

The carbo-triassic series continues to crop out east of Chuári, but it becomes greatly attenuated in this section. The bridge over the Chaki (Chuckee) below Raipur (Rapir) is on the limestones of this series, but the band is apparently a thin one; whilst in the bed of the Chanál, under Sraog, the whole outcrop of this series does not attain a thickness of much more than 50 or 60 yards.

The Dalhousie altered basalts crop out next the limestones at the bridge under Raipur, and thereafter the road runs with these rocks to the vicinity of Samót (Samoat), where they, in their turn, disappear. I failed to obtain any trace of them east of this point. Samót, and the land between it and Sihunta, is, for the most part, well covered with post-tertiary alluvial deposits, but I searched carefully along the beds of streams and I am satisfied that the trap dies out

[1] Records XV, 34.

[2] My reasons for calling the outer band gneissose granite are given in a paper to appear in the next number of the Records.

between Samót and Sihunta. A good section is obtained in the bed of the Chanál under Sraog, and only about 50 or 60 yards of the carbo-triassic series interposes there between the siwalik sandstones and the mica schists of the lower silurians.

In my paper on the Dalhousie area, I noted that the sirmur series had been cut out by a fault south of Chuári, and the conglomerates of the siwalik series brought into contact with the trap. This feature appears to persist in the Chuári and Sihunta section. At Kanóra (apparently Samoat of the map)[1] a coarse breccia resting on red clay, dipping N.-N.-E. at a low angle, is in contact with the trap. These rocks, and those which occur further east, are of siwalik aspect; and I did not, in this region, see any rock along the inner horizon of the tertiaries that I could identify as a member of the sirmur series.

I made an excursion up the Diarh *nadi* one day and found that the gneissose granite appeared exactly where I expected to find it north-east of Tikri (Tikiria). At Tikri, the rocks on both sides of the stream are silurian slates, and they continue up to the gneissose granite with a dip to E. 11° N.

In the hills north-east of Sihunta a surprise awaited me. About three quarters of a mile, as the crow flies, from the horizon of the carbo-triassic series, a fine-grained gneiss, or gneissose granite, crops out to the north of Sraog at an elevation of 4,100 feet, and 1,000 feet above Sihunta. The rock is a perfectly crystalline combination of quartz, felspar, muscovite and dark mica, but exhibiting a well-marked foliation or parallelism of structure. In weathered boulders it is not possible to distinguish between it and the fine-grained, non-porphyritic variety of the Dhúlar Dhár gneissose granite. Higher up the ridge, the Sraog rock becomes more schistose in aspect, and finally becomes superficially very rotten from weathering. The transition from this fine-grained rock to the larger-grained highly porphyritic gneissose granite of the Dhúlar Dhár is a sudden one. The fine-grained rock appears to be older than the porphyritic gneissose granite, for I observed a large boulder of the former in an affluent of the Chanál close to and east of Sihunta, which contained large intrusive veins of the coarser-grained porphyritic rock. An examination of these veins left no doubt in my mind of their intrusive character.

There seems no ground for supposing that this fine-grained foliated Sraog rock is an extension of the Dalhousie "outer band." The latter occurs below the mica schists and a great thickness of the silurian slaty series interposes between it and the porphyritic gneissose granite. The Sraog rock, on the contrary, occurs above the mica schists and slates, and appears to be in contact with the porphyritic gneissose granite.[2] Moreover, though they are composed of the same minerals, there is no resemblance in their macroscopic aspect between hand specimens of the "outer band" and the Sraog gneiss.

[1] The real position of Samót is apparently where Kania is marked on the map. Tundí bears N.-W. from Samót, not S.-W. as shown on the map. I tried every conceivable mode of pronouncing Kania, but no name at all like it was known in Samót.

[2] I climbed the ridge to an elevation of 6,200 feet, and reached a point abreast of Tikri. I had no time to go higher, moreover it was blowing half a gale; a snow-storm was coming on, and the natives with me were suffering acutely from the cold.

On my ascent, my way lay for some distance up a stream between Sraog and Pukuru. The actual contact of the gneiss and the slates was not visible there; but on my descent along a spur of the mountain by another route, the passage from gneiss, or gneissose granite, to indurated slates was sudden. These slates are highly altered, and indeed assume quite a foliated aspect when in contact with the gneiss. A little further on, the gneiss re-appeared again for some yards, and then slates similar in character to the first.

The dip of the mica schists and slates between Sraog and the gneiss varied from N.-E. to N.; and, taken in connection with the E. 11° N. dip of the slates at Tikri, they would thus appear to dip into the gneiss all round. The mica schists and slates appeared to me to be lower and middle silurians.

Whether the Sraog rock is another case of the intrusion of gneissose granite or whether it is of pre-silurian age—the remains of ancient land on which the silurians were deposited—is a question regarding which I think it would be premature to offer an opinion in the present paper. Careful field work, and microscopic investigation in the laboratory,[1] will need to go hand in hand for a long course of years before all the details of Himalayan geology can be successfully worked out.

The spurs south-west of Tikri and north-west of Samót are so thickly covered with boulders that I could only get a glimpse in one place of the slates on which they apparently rest, though I traversed these spurs for some miles. Indeed, so thickly are these boulders scattered over the hill sides, that the suspicion crossed my mind that a local eruption of granite had taken place at this spot and that the boulders had weathered out *in situ*. I could find no evidence, however, to support this idea, for even when small landslips had removed the superficial vegetable deposits nothing was revealed but broken boulders beneath.

The next idea that naturally occurred to the mind to account for these accumulations of boulders was glacial action; indeed not only here, but all round Sihunta and on the road between that place and Chuári, huge blocks of granite are scattered about over the hill sides in a way to suggest the former existence of such action very strongly. Blocks are found perched on the undulating edges of spurs and dotted over the sloping sides of the mountains. The alluvium of the valley is studded with them; accumulations of boulders here and there assume a very moraine-like appearance; whilst the heads of little upland valleys, formed by the bifurcation of spurs, where evidently no stream of any consequence has ever flowed, are thickly strewn with them.

One block, measuring 26 × 19 × 7, I found perched on the crest of a ridge west of the Dairh river, on the Chuári road, at an elevation of 4,000 feet and 1,200 feet above the present bed of the Dairh. Another block, measuring 29 × 25 × 18—and there are numbers of others of about the same size—I found at an elevation of 3,000 feet above the sea, resting on the surface of a rice-field on the south side of the valley at Sihunta.

The antecedent improbability of a glacier at the latitude of 32° 18 extending

[1] As I have only just returned from this trip, I have not had time to examine thin slices of the Sraog rock under the microscope.

down as low as 2,000 feet above the sea—for the blocks go down at least as low as that—is very great; but it might be argued that water power could not be called in to explain the transport of a block containing 13,050 cubic feet of granite; for a rush of water of sufficient volume and velocity to carry 13,050 cubic feet of granite in a single block down a slope of about 1 in 20 would have scoured out the whole valley and carried away every particle of the soft alluvium with it; whereas these blocks are not found buried in a boulder bed surrounded with shingle, but resting on the surface of a thick deposit of soft mud. These and other arguments that could be advanced to prove the former presence of local glaciers, seemed to me unanswerable, until I found that a gneiss, or gneissose granite, large weathered blocks of which are undistinguishable from similar blocks of the fine-grained variety of the Dhûlar Dhâr granite, occurs as low down as 4,100 feet above the sea. Now that we know that this massive rock crops out within three quarters of a mile of the siwalik horizon, and less than 2 miles from Sihunta, the difficulty is in a great measure removed, and it does not seem necessary to resort to a glacial theory to explain the presence of blocks so near their place of origin.

Note on the occurrence of the genus LYTTONIA, *Waag., in the* Kuling Series *of* Kashmir, *by* R. LYDEKKER, B.A., F.G.S., F.Z.S.

Since the publication of my memoir on the Geology of Kashmir[1] a new genus of brachiopods, from the "Productus-limestone"[2] of the Salt-range and adjacent districts, has been described by Dr. Waagen under the name of *Lyttonia.* The genus has also been obtained in the carboniferous of China.

On seeing the figures of the Salt-range specimens, I at once recognised fossils not unfrequently occurring in the Kuling series of the neighbourhood of the Kashmir valley, whose affinities I had long been at a loss to determine. They are found on weathered surfaces of the limestone rocks in several parts of the northern side of the valley, but more especially on the high ridges to the north-east of Sirinagar. The rock in which they occur is so hard that I was unable to chisel out specimens sufficiently perfect to carry away.

Judging from memory, I think that the common Kashmir form is *L. nobilis.* It is a fact of much interest to find this remarkable genus adding another to the long list of forms common to the "Productus-limestone" and the Kuling series of Kashmir.

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A pair of quernstones made of arkose, from near Dhararah, Monghyr District.

PRESENTED BY MR. R. S. BION.

Four specimens of marble, from Jaipur and Ajmere.

PURCHASED.

6 specimens of Bhanrer (Vindhyan) sandstone from Rupas quarries, Bhartpur.

PURCHASED.

[1] "Memoirs," Vol. XXII.

[2] "Pal. Ind.," Ser. XII, Vol. II, pp. 396-406; plts. XXIX—XXX.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1884. [May.

Note on the Earthquake *of 31st December 1881, by* R. D. OLDHAM, A.R.S.M., *Geological Survey of India.* (With a map.)

On the morning of the 31st December 1881 a severe earthquake was felt over a large portion of the Indian peninsula and Bengal, affecting also the Burmese coast and causing much damage in the Andaman and Nicobar islands. A considerable amount of material, comprising newspaper extracts, official reports and private letters, having been placed at my disposal, I propose giving a brief notice of the more important features of the shock.

In Bengal it was felt as far as Chùnar (?), Gaya, and Hazaribagh; Akra, in the 24-Parganas, was shaken; and at Akyab it was followed by the eruption of a mud volcano in Ramri.[1] There is no record of its having been felt at Rangoon or Moulmein; at Tenasserim it is doubtful, though it was felt in the Mergui archipelago; to the south it is reported as having been 'severe' at Acheen in Sumatra, and in N. Lat. 3° 54′, E. Long. 91° 21′ it was felt by the ship *Mount Stuart;* at Ootacamund it is recorded, as also at Calicut: thus the area over which it was felt measures about 1,600 miles from north to south and 1,500 miles from east to west, or 2,000,000 square miles in all.

Such briefly is the summary of the information contained in the daily papers, and as no observation of scientific value is recorded in them which has not been placed at my disposal in another form, I shall refrain from repeating the vague, when not misleading, statements of the time and nature of the shock which were so given to the world.[2]

There is, however, one published notice which contains much valuable information. I refer to the note by General Walker, and Major M. W. Rogers, R.E. (originally published in the Annual Report of the Trigonometrical Survey, and

[1] Records, G. S. I., Vol. XV, p. 141.

[2] I may, however, mention one letter by Mr. W. G. Simmons of Calcutta published in the *Indian Daily News.* He seems to have been at some trouble to collect information, and I have to thank him for liberally placing it at my disposal.

reprinted in the Proceedings of the Asiatic Society of Bengal, March 1883, page 60) on the records left by the earthquake, and its consequent sea-wave on the tidal gauges fixed along the shores of the Bay of Bengal, illustrated by reductions from the original records and a chart of the Bay of Bengal, on which Major Rogers has marked what he considered to be the focus of the disturbance. For the benefit of those who may not have access to the original, I subjoin a short abstract of the information contained.

At Port Blair, the forced sea-wave, indicating the arrival of the earth-wave, is indicated at 7*h*. 44′;[1] the first sea-wave arrived at 8*h*. 3′, followed by others at 15 minutes interval, with a height of 3 feet from crest to hollow, the disturbance not subsiding entirely till 21*h*.

Diamond Harbour.—Sea-wave hardly perceptible; arrived at 15*h*. 10.′

Dablat.—First sea-wave at 13*h*.; disturbance continued till 21*h*.

False Point.—Forced sea-wave at 7*h*. 54′. Sea-waves small; the first arrived at 11*h*. 15.′

Vizagapatam.—The sea-wave arrived at 10*h*. 43′, followed by others until midnight.

Madras.—Sea-wave arrived at 10*h*. 18.′

Negapatam.—The first wave, which arrived at 10*h*. 15′, measured 4 feet from crest to hollow, and was followed by others until midnight.

Paumben.—First wave at 11*h*. 32′; disturbance lasted till midnight.

At Calcutta the time of arrival of the earthquake was noted by Mr. James Murray, who writes, in reply to my enquiries, that he was reading in an upstairs room when feeling the shock he immediately ran downstairs and marked on the glass of his standard regulating clock the exact position of the second's hand and then waited to note the time of cessation of the motion; afterwards he carefully took with a second's watch the time that it occupied to do all he had done between the moment when he first felt the shock and when he made the mark on the glass of his clock, adding this and the error of the clock on that morning, he obtained the times of commencement and cessation as 7*h*. 37′ 45″ and 7*h*. 42′ 0″, Calcutta mean time, or 7*h*. 55′ 2″ and 7*h*. 59′ 17″ Port Blair mean time, respectively. This, I may add, is the only observation of real value made at the time and not automatically recorded that I know of in connection with this shock.

At Madras a clock in the office of the Master Attendant, electrically controlled from the astronomical observatory, was stopped at 7*h*. 5′ 45″ local time, or 7*h*. 55′ 36″ Port Blair mean time.

Port Blair is the only place where any damage was done to masonry buildings, and it is to be regretted that the damage should be so little instructive as is the case. The infantry barrack, of which I have drawings showing the damage done, is a long, narrow building situated on the crest of a hill, the major axis bearing N. 20° E., while the cross-walls bear E. 20° S. The latter were severely cracked, while with a single exception not a crack has opened in the longitudinal walls; this might indicate a direction nearly N. 20° E. or S. 20° W., but

[1] These times differ from those originally given, having been retaken with greater care from the original records. The times here and throughout this notice are reduced to Port Blair mean time, and for the sea-wave are the time of arrival of the crest of the first wave.

is most probably, as will be seen from the sequel, due to their being of less solid construction. As regards the angle of emergence the cracks do not indicate much, merely pointing to a nearly horizontal or nearly vertical emergence; the former would be indicated by the fact that a chimney shaft 60 feet high was cracked but not overthrown as it certainly must have been by a severe shock with a moderate angle of emergence, but as this supposition is irreconcileable with the position of the seismic vertical obtained from more trustworthy observations we must suppose the angle of emergence to have been nearly horizontal and the violence of the shock to have been considerably exaggerated.

In the Car Nicobar extensive damage was done to the cocoanut groves and huts of the natives, and vents similar to those described in connection with the Cachar earthquake of 1869[1] were opened in the sandy soil. It was noted by Major W. B. Birch, to whose report I am indebted for the facts, that on the margin of the seashore the trees were left standing, while further inland they were overthrown. This may have been due to the fact that the edge of the land was protected from the earthquake by the slope of the seaward face being steeper than that of the emergence of the wave but I am inclined to believe that Major Birch's suggestion, that the soil near the sea margin is firmer than that further inland, is more likely to be the true explanation. The sea-wave broke on this island and it is recorded that the water penetrated into the houses of the Burmese residents which stood on platforms of less than $2\frac{1}{2}$ feet high, while those on higher platforms escaped.

I will now proceed to the discussion of the data available, which are, *firstly*, the records of the arrival of the earth-wave at Calcutta, Madras, False Point, Port Blair, and Kisseraing; and, *secondly*, the records of the arrival of the sea-wave at the stations mentioned above; the latter, however, are owing to irregularities in the depth of the Bay of Bengal of no use in determining the position of the seismic vertical. Of the first category, the records from Madras and Calcutta are undoubtedly good, those from Port Blair and False Point are good as far as they go, but only pretend to give the time to the nearest minute, while the fifth is, as will be subsequently shown, unfortunately open to an element of doubt.

It has been pointed out by Professor Milne that if the earth-wave arrives at two points on the earth's surface at the same moment of absolute time and a straight line be drawn joining those two points, the seismic vertical should lie somewhere on the line bisecting it at right angles, supposing, that is to say, that the surface of the earth were a plane and its substance homogeneous; on the same suppositions if the time of arrival is known at three stations and circles be drawn round the two at which the arrival was latest with radii equal to the distance traversed by the wave in the respective absolute differences of time between its arrival at those stations and at the first station, and a circle be drawn passing through the first station and touching the circles drawn round the second and third stations, the centre of that circle will represent the position of the seismic vertical. Neither of the assumptions are, of course, theoretically correct, but these constructions give a rapid and convenient method of finding the approximate position

[1] Memoirs, G. S. I., Vol. XIX, part I.

of the seismic vertical. I have, for the purposes of the first construction, taken the time of arrival at Calcutta and Madras as identical and represented it on the map by fine firm lines; the second construction is not represented, but the centres obtained are indicated by dots with the letters C. M. B. for the centre deduced from the Calcutta, Madras, and Port Blair observations, and F. M. B. for that due to those at False Point, Madras, and Port Blair. It will be seen that the first-named lies within 30 miles of the true position of the seismic vertical, the error being due almost entirely to the unavoidable distortion of the map; the other shows a greater error, due partly to a less average accuracy of the observations and partly to the fact that the stations are less favourably situated for applying the construction. Taking Calcutta, False Point, and Port Blair, we get an impossible centre at the mouth of the Irrawadi, the fact being that this construction is only practically applicable when the three stations form a pretty open triangle. The Madras, False Point, and Kisseraing observations give the centre where Major Rogers placed it, but this result is vitiated both by the small inaccuracy of the False Point observation and the greater one at Kisseraing, which will be referred to hereafter.

Starting with the C. M. B. centre, a brief investigation proves it to be about 30 miles too far south; so taking Lat. 15° Long. 89° as the centre provisionally, we find that the geodetic distance from this point to

	Feet.
Port Blair is	1,804,475
Calcutta is	3,117,585
False Point is	2,888,620
Madras is	3,177,850
Kisseraing is	3,563,660

Subtracting the distance to Port Blair and dividing the results by the respective differences of time, we get a velocity of transit as between Port Blair and

	Feet per second.
Calcutta of	1,957
Madras of	1,948
False Point of	1,807
Kisseraing of	2,666

and as between Calcutta and Madras of 1,746 feet per second—a not impossible result, as the difference of distance would lie mainly in alluvial deposits, though possibly indicates that the centre is about half a mile east of the position assumed.

The low velocity as between Port Blair and False Point is easily explicable by the fact that the observations are only given to the nearest minute; had the time interval been 9 minutes instead of 10 minutes, it would give a velocity of 2,001 feet per second, while an interval of 9¾ minutes would bring it almost into accord with the Calcutta and Madras observations. From this we may conclude that the time recorded at Port Blair is too early, or that at False Point too late, or possibly both. It must be borne in mind that the times were taken from the trace left by a pencil on a sheet of paper and on a scale on which it would be difficult to distinguish between, say, 7*h.* 53′ 15″ and 7*h.* 53′ 45″, though one should be recorded to the nearest minute as 7*h.* 53′ and the other as 7*h.* 54′.

The Kisseraing observation, however, gives a velocity which is inexplicable

on this supposition, and I cannot but consider the error due to an actual error of observation, as, though it can be approximately reconciled with those from the western stations, this can only be done by taking the latter out of accord with each other and giving an inadmissibly high velocity to the whole series. The only published record of this observation is that in Major Roger's note, where he says that "at Madras, False Point, and Kisseraing the shock was felt at about the same minute—*7h.*·55′ A.M.;" it will be seen that this is rathor vague, and a personal application to Major Rogers elicited the fact that the original record had been destroyed, and it was consequently no longer possible to estimate the degree of accuracy of the time record. I fear we must reject this observation as of insufficient accuracy for the purposes of the investigation.

The position assumed above proves to be that which best reconciles itself to the excellent observations at Calcutta and Madras, and to the automatic records at Port Blair and in a less degree False Point; I shall consequently consider that the shock did originate vertically below a point situated in Lat. 15° N., and Long. 89° E., and that it travelled with a velocity of 1,950 feet per second, being that indicated by the Madras and Calcutta and Port Blair observations. Under these circumstances the time taken by the earth-wave to travel from the seismic vertical to

Port Blair would be	15′ 25″
Calcutta „	26′ 39″
Madras „	27′ 9″

(I omit Kisseraing and False Point owing to probable inaccuracies of the records.)

Subtracting these intervals from the recorded times, we have the Port Blair mean time of the origin of the earthquake deduced from the

Port Blair record as	*7h.* 28′ 35″
Calcutta „ „	*7h.* 28′ 23″
Madras „ „	*7h.* 28′ 27″
Mean	*7h.* 28′ 28″

But as the Port Blair record is liable to an unknown error being merely to the nearest minute, the mean of the Calcutta and Madras results, *viz.*, *7h.* 28′ 25″, is probably more accurate. Taking this result and reckoning back to the various stations we get the true time at

Port Blair,	*7h.* 43′ 50″	instead of	*7h.* 44′, a probable error of	+ 10″
False Point,	*7h.* 53′ 6″	„	*7h.* 54′ „ „	+ 54″
Kisseraing,	*7h.* 58′ 58″	„	*7h.* 55′ „ „	—3′ 58″

The depth of the focus below the level of the sea cannot unfortunately be ascertained, the only records that could give the angle of emergence being from Port Blair and, as mentioned above, they are indefinite, and all we can say is that the emergence was nearly horizontal; from this we would deduce a focus situated at a small depth, probably about 5 or 10 miles, and being improbably over 15 miles from the surface.

In the shape of the area over which the shock was felt there is a notable peculiarity as regards its eastern boundary between Akyab and Tenasserim, which seems to be real and not merely due to insufficient information, for Rangoon and Moulmein are large cities with a considerable resident European population, so

that the shock if felt could hardly have escaped record.[1] In the Mergui a pelago it is recorded as slight, and it is very doubtful whether it was fe Tenasserim. To the south, west, and north the configuration is very diffe the shock is recorded as severe at Acheen; it was felt by the ship *Mount S* in N. Lat. 3° 54′ E. Long. 91° 21′; to the west it was felt at Calicut to the north is said to have been felt at Chunar, though Gaya is po the extreme limit. This peculiarity may in part be due to a difference i rocks traversed, but not being fully accounted for in that manner clearl dicates that the shock had its origin in a fissure underlying strongly to the If we accepted the Chunar record, it would almost be necessary to suppo fissure curved and bending round from about S.-W. to S.-E, rejecting come to the conclusion that this earthquake had its origin in a straigl nearly straight, fissure bearing about N.-W. and S.-E. and underlying t S.-W., a far more probable configuration than the first, and one which i absolutely incompatible with the Chunar record, if that is correct.

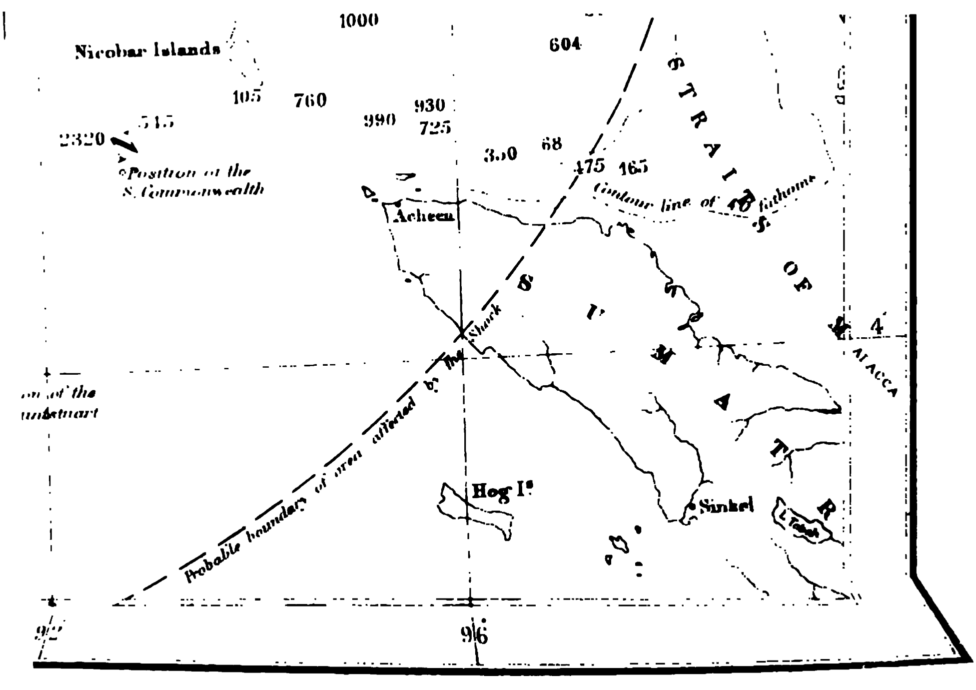
When we come to examine the records of the tide gauges the first to be noticed is the absence of any record from the stations on the Burmese while the wave is shown to have reached points on the western coast of th situated at a greater distance from the centre. This, however, ceases to be rer able when we examine the records from the stations on the delta of the Ga At Dablat the height of the wave is 12 inches, while at False Point it i 2 inches, and merely perceptible at Diamond Harbour; if on the delta of the Ga exposed to the full force of the wave, the mere shoaling of the waters proc such an effect, it is not surprising that a similar shoaling at the mouth c Irrawadi should have entirely destroyed the wave already enfeebled by barrier stretching between Cape Negrais and the Andaman islands.

Between the centre and Port Blair the wave must have travelled by cuitous route, and as it is impossible to say what allowance is to be made for it becomes impracticable to correctly calculate the rate at which it travelled all probability the first wave recorded came round the south of the island, the curve bears ample evidence that the subsequent long-continued and co cated disturbance was due to the interference of the two sets of waves- travelling from the north, the other from the south.

Taking, for convenience of calculation, the time of origin of the wa 7*h*. 28′ 30″, the error so introduced being comparatively insignificant, and i case certainly not greater than that due to want of accuracy in the records find that the mean rate of transit of the wave between the centre and

		Feet per second.
Paumben	is	281
Negapatam	,,	359
Madras	,,	311
Vizagapatam	,,	173
False Point	,,	213
Dablat	,,	104

[1] As this note was passing through the press a paper on 'Earthquake disturbances Tides on the coasts of India,' by Lieutenant-General J. T. Walker, C.B., F.R.S., etc., ap in 'Nature,' February 14th, in which it is incidentally mentioned that the earthquake w at Rangoon and Moulmein.



1000
Nicobar Islands
604
105
760
990
930
725
2320
68
475
165
Acheen
Hog I.
Sinkel
4
92
96

Of these, the difference between the mean rates to Negapatam and Paumben is due to the long stretch of shallow water crossed in the latter case; but the difference between Madras and Negapatam is noticeable, and is probably due to the shallowing of the bay by the deposit in it of the silt brought down by the Kistna and Godavery rivers; this same cause has evidently affected the velocity between the centre and Vizagapatam, while the increase in velocity between the centre and False Point indicates that the wave has travelled over the depression between the two banks caused by the deposit from the Kistna and Godavery on the one hand and the Ganges and Brahmaputra on the other.

This notice, besides its direct bearing on the earthquake in question, shows the great value of a few really accurate time observations which, taken in conjunction with such simple observations as are within the power of all to make, have enabled me to fix the position of the seismic vertical, the velocity of transmission of the earth-wave, and the approximate form of the focus; had it originated inland there might not improbably have been sufficient information available to fix the depth of the focus—in the present state of our knowledge, one of the most important, if not the most important point to be determined with some degree of accuracy. Under these circumstances it is unfortunate that in the system of seismological observations recently sanctioned by Government an accurate determination of the time could not be incorporated, but with the unskilled even where not unsympathetic observers who are alone, as a rule, available, it would be impossible to secure that accuracy of record which alone would be of use; for this is especially a case where an inaccuracy, where accuracy is looked for, is worse than no record at all.

The following facts, though not strictly related to the earthquake under consideration, may with advantage be put on record here.

The master of the ship *Commonwealth* reported that he felt three shocks of earthquake on the 1st January 1882 in N. Lat. 8° 20′, E. Long. 92° 42′, and that the whole of the Car Nicobar was hidden by smoke. Major Birch on his subsequent visit to the island could find no foundation for this statement, so that in all probability it was only the smoke of a fire that was seen.

This shock was stated in the daily papers to have been felt at Khatmandu, in Nepal; but to judge from the more detailed information placed at my disposal, this cannot have been the same shock.

On the Microscopic structure *of some* Himalayan granites *and* gneissose granites, *by* COLONEL C. A. McMAHON, F.G.S. (With a Plate.)

In my paper "On the microscopic structure of some Dalhousie rocks,"[1] I have already given an account of the structure of the gneissose granite of Dainkund, Dalhousie. This paper is occupied with a description of the "outer band" of gneissose granite at Dalhousie, called gneiss in my previous papers, and of gneissose granite found in the Sutlej valley, and in the Chor mountain near Simla. I have also, for the sake of comparison, described the microscopic structure of some

[1] Records, Vol. XVI, p. 129.

undoubtedly eruptive granites, which invade silurian and cambrian (?) rocks in the Ravi and Sutlej valleys.

In this paper I propose to follow my usual custom, and begin with a somewhat detailed account of the several specimens, and conclude with some general remarks by way of summing up the results of my investigation.

1. Granite intrusive in the schists above Darwás, from a dyke on the road between Darwás and Kilar, Pángi valley, Chamba.[1] The hand specimen shows the junction of the granite and the mica schists. A parallelism of structure, evidently due to traction, is, to a certain extent, observable in the granite. Schorl is abundant in the hand specimen, but none occurs in the slice.

M.—Quartz, orthoclase, and a silvery mica, are abundant, and there is a little triclinic felspar.

The quartz is hyaline, and contains a prodigious number of liquid cavities. Most of the orthoclase is white and opaque. The slice contains a large garnet of decidedly pink colour in transmitted light; part of it is decomposed. There are several belonites, but they do not contain any shrinkage cavities.

Viewed macroscopically, the mica is of a brilliant silvery metallic lustre, but under the microscope it is dull, and shows no colours under the polariscope.

Nos. 2, 3, and 4.—Granite intrusive in quartzite and in schistose rocks at Leo, on the Spiti river. It occurs in dykes and veins varying in thickness from 30 feet to a fraction of an inch, and penetrates the rocks in all directions. (See Records, Vol. XII, p. 60.)

2. A fine-grained granite.

3. A medium-grained granite. Muscovite having a brilliant silvery lustre is very prominent. Schorl is not visible to the naked eye. The felspar is of dull white colour, differing little in tint from the quartz. A pink garnet is visible in the hand specimen.

4. A fine-grained granite. Scarcely any muscovite is to be seen with a lens, but well-crystallised minute prisms of schorl are very abundant, and give the rock a speckled appearance.

M.—The quartz in these specimens is almost wholly of polysynthetic structure, similar to the "fish roe" quartz of the Dalhousie gneissose granite. It contains liquid cavities with movable bubbles, though not in great abundance.

Orthoclase and plagioclase are both present, and, apparently, in nearly equal quantities. The twinning is very fine, the lamellæ being extremely thin. In some crystals they are slightly curved out of the perpendicular; in other felspars cracks have been formed subsequent to the twinning, and have been filled with quartz; whilst in one instance the twinning has been faulted by a diagonal fracture. All these circumstances seem to indicate conditions of strain connected with the intrusion of the granite into the sedimentary rocks.

Muscovite is abundant in all the specimens, and in all it polarizes in delicate colours, but with extreme brilliancy, as in the Dalhousie gneissose granite. All the slices contain schorl, garnets, and a little green mica. In No. 3, the schorl and garnets are in strings, having a common direction, the result doubtless of traction. The garnets contain enclosures with fixed bubbles, and one of the en-

[1] Records, Vol. XIV, p. 308.

closures is apparently a "stone cavity." Quartz enclosures are common in the schorl.

Neither magnetite nor ilmenite is present, but red ferruginous stains are not uncommon.

Nos. 5 to 12.—Granite from the cliffs above Jángí, Sutlej valley. I have described the mode in which the granite occurs in previous papers (Records, Vol. X, p. 221; Vol. XII, p. 57). The result of its study in the field on two occasions left no doubt in my mind of its intrusive character. The rock is white and fine-grained, and is composed of quartz, felspar, and biotite.

M.—Quartz is more abundant than felspar, but not notably so. Plagioclase is sparse, and is very subordinate to the orthoclase. All the slices contain microcline, except No. 7.

Garnets are present, but they are very small; some of them contain liquid cavities with extremely minute movable bubbles.

Biotite is plentiful; it occurs in large groups, in which the folia are oriented in all directions and the basal cleavage is strongly developed, and also in the form of minute rounded or hexagonal-shaped microliths scattered abundantly through the ground mass. Elongated microliths of it are also present, but they are not so numerous. It is of rich brown-green and green-brown colour in transmitted, and deep black in reflected, light.

Except in the form of microliths, muscovite is extremely scarce. The only piece of any size occurs imbedded in a group of biotite. Thousands of microliths of this mica are crowded together in many of the felspars in a way exactly similar to that described in my paper on the gneissose granites of Dalhousie.[1] At times, they are scattered about in a promiscuous manner; at others, they conform to the direction of the cleavage planes of the felspar.

In the slices of the Jángi granite under consideration, and in the gneissose granite of the Sutlej valley generally, these muscovite microliths—for such I take them to be—frequently assume very curious combinations, imitative or suggestive of organic structures, the result, I apprehend, of the imperfect development or arrested crystallisation of these microliths. At fig. 9 I have sketched a dendritic combination that occurs in one of the slices.

At fig. 10 I have given a sketch of crystals formed within a crystal ("stone enclosure") with a contraction bubble, due to shrinkage on cooling. This illustration is taken from slice No. 8. As the Jángi granite is undoubtedly an eruptive rock intrusive in the schists in which it occurs, it is interesting to compare the enclosures contained in it with those of rocks whose eruptive character is more doubtful.

Figs. 11, 12, and 13 are sketches of microscopic crystals (greatly enlarged) found in slice No. 7, which are typical of the kinds of enclosures not uncommon in the granites and gneissose granites of the Sutlej valley. No. 11 contains numerous cavities with contraction bubbles in them. No. 12 encloses stone cavities, or crystals, with bubbles in them, and gas cavities; whilst No. 13 contains cavities and crystals, one of the former of which holds a nearly rectangular crystal. The crack observable in No. 11 is probably due to shrinkage on cooling. Enclo-

[1] Records, Vol. XVI, p. 131.

sures, such as those depicted, are characteristic of igneous rocks; they show that the mass which contains them was subjected to great heat and was reduced to a more or less fluid or plastic condition; that the crystals under observation contracted on cooling, and that they either caught up the micro-crystals and the fluids and gasses now enclosed in them in the act of crystallisation, or that the mineral matter at the time of consolidation deposited these endo-crystals, and the fluid and gas, held in solution, or occluded in it, when at a high temperature.

No. 13.—Granite from a dyke near Rárang, Sutlej valley. This dyke (Records, Vol. X, p. 221) is about 300 or 400 feet wide, and cuts through thin-bedded mica schists up to the crest of the ridge, sending out large lateral veins into the schists. It is a very fine-grained rock, of much darker colour than the last, owing to the abundance of biotite present in it. The felspar is very glassy looking, and much resembles quartz in colour and aspect. A parallelism in the arrangement of the biotite, resembling incipient foliation, is, to a certain extent, observable.

M.—Quartz predominates over the felspar, and orthoclase is very subordinate to plagioclase. The slice contains no muscovite, except in the form of microliths. There are a few small garnets. In general characteristics this rock much resembles the Jángi granite, and doubtless it is only a variety of it.

The quartz contains numerous liquid cavities. The great majority of them are without bubbles; others have fixed bubbles and some few movable bubbles. A flattened variety of liquid cavity, with a fixed bubble, is common.

Several of the microliths have elongated shrinkage cavities or bubbles.

No. 14.—Granite from the centre of a dyke intrusive in mica schists at Pángi, Sutlej valley.[1] A fine-grained white granite, containing white felspar quartz, muscovite, biotite, and schorl. The muscovite is in hexagonal-shaped packets.

M.—Quartz is decidedly subordinate to felspar; plagioclase to orthoclase, and biotite to muscovite. Schorl and garnets are present. The muscovite is well crystallised and is in hexagonal plates. The cleavage of both muscovite and biotite is strongly developed, and some of the biotite is enclosed in muscovite.

The felspar is free from microliths of muscovite and biotite. A little microcline is present.

One of the garnets—or what I doubt not is a garnet—exhibits double refraction. It is colourless in transmitted light, and is evidently unaltered, so that the double refraction is not due to alteration. The garnet is also too large, and the slice is too thin to admit of the supposition that the section of the mineral under examination is superimposed on a slice of quartz or felspar, so its abnormal behaviour between crossed nicols cannot be attributed to the intervention of a doubly refractive medium. I have sometimes observed the peculiarity now noted in garnets in the gneissose granites, though the double refraction is usually very feeble.

One variety of garnet, colophonite, is said to exhibit double refraction; and, *vide* E. S. Dana's Appendix III, page 50, garnets are considered pseudo-isometric, and are referred to the triclinic system by Mallard and Bertrand. But may not

[1] Records, Vol. X, p. 221.

the occasional and generally very feeble double refraction of some of the garnets of the granites and gneissose granites of the North-West Himalayas be due to strain and be simply one of the results of pressure consequent on intrusion? It is well known that glass subjected to strain exhibits double refraction.

Liquid cavities, with fixed and movable bubbles, are abundant. The bubbles are of good size, and for the most part cover about half the area of the cavity, indicating a condition of very great heat and great subsequent contraction on cooling. The whole aspect of the rock shows that the granite, when injected into the schists, was in a completely fused or fluid condition, and cooled slowly, hence the perfectly crystalline condition of its component minerals.

No. 15.—Granite from another large dyke: Pángi, Bassáhir. Similar dykes are rather numerous in the gneissose granite between Wangtu and Pángi. Muscovite is plentiful, and a dark-green mica is rather abundant. Schorl is present in some quantity. The felspar assumes a green appearance here and there, owing apparently to the deposit of a thin superficial film of chlorite.

M.—Orthoclase is more abundant than quartz. Plagioclase is present, but in very small quantity. The double refraction of the muscovite is so great that the thinnest sections of it only show the feeblest colours in polarized light. The basal cleavage lines of the green mica are well developed in some sections. Mica is not present in the form of microliths.

Liquid cavities with movable bubbles are extremely numerous both in the quartz and in the felspar. As in the last specimen, the bubbles are large relatively to the size of the cavities, and they are remarkably lively. Much of the felspar is opaque owing to the abundance of the enclosures in it, partly liquid and partly unresolvable ones. The slice contains gas cavities, but they are not abundant. I cannot call to mind any rock in which liquid cavities are more abundant than in this specimen. I have not observed a single microlith in this slice.

As in the last rock described, this granite was evidently subjected to intense heat, and reduced by igneo-aqueous action to a fused condition and subsequently cooled slowly.

Nos. 16 to 19.—Gneissose granite: Wangtu[1] Sutlej valley, Bassáhir. These specimens contain an abundance of very black biotite, in the arrangement of which parallelism of structure is very distinct.

M.—In these slices orthoclase largely predominates over the plagioclase; whilst quartz and felspar are present in about equal proportions. Biotite and muscovite are both present; the former predominates in leaves of other than microscopic size, but the muscovite is abundant in micro-crystalline agglomerations in the form of microliths in the felspar, as described in the Jángi granite, slices 5—8.

The dendritic combinations described in connection with the Jángi granite occur in these slices, and fig. 9 is taken from one of them.

The quartz in these slices occurs in grains of moderate size, and also in fish roe grains, the latter showing a decided tendency to assume hexagonal outlines.

[1] A brief allusion to the rocks at Wangtu is contained in my paper in the 10th Volume of Records, pp. 218, 219.

The quartz contains numerous liquid cavities with bubbles, some of which are movable. Much of the felspar is very opaque; but in some the intersection of the basal and clino-diagonal cleavage planes is well seen.

This rock has all the appearance under the microscope of an ordinary granite of eruptive origin.

Nos. 20 and 21.—Granite from the neighbourhood of Wangtu.

M.—Plagioclase is the predominating felspar, though orthoclase is also present.

Microcline is abundant and is of typical character. In slice No. 14 one of the crystals is of large size. The orthoclase and microcline taken together, equal, or nearly equal, the plagioclase.

Schorl is abundant, and contains numerous inclusions of quartz. Biotite and muscovite are present, but in small quantities. The quartz is very subordinate in amount to the felspar.

Liquid cavities with movable bubbles abound in the quartz, and I have observed some with fixed bubbles in the felspar. The bubbles are of good size, and the area of the cavities appears, at a rough guess, to be about two and a half times that of the bubbles contained in them.

The quartz enclosed in the schorl contains liquid cavities with movable bubbles, whilst the schorl itself contains cavities with fixed bubbles. There are some microliths containing what appear to be shrinkage cavities in them.

Beryl from a granite dyke near Wangtu, Sutlej Valley.—I have beryl taken from a granite dyke which is intrusive in the gneissose granite at Wangtu enclosed in quartz, in felspar, and in muscovite, and it is therefore clear that beryl was the first mineral to crystallise. An examination of thin slices of the beryl under the microscope is particularly interesting, as it enables us to ascertain the condition of the fused mass at an early stage of cooling before the quartz, felspar, and muscovite had begun to crystallise.

The examination of these slices shows that the magma must have been in a fluid state, and that a considerable amount of heated gas, water, and carbon dioxide were intimately blended with it in a superheated condition when the beryl crystallised.

The number of enclosures containing bubbles to be seen in these slices is quite extraordinary. The enclosures are of various shapes; some are hexagonal, others are more or less round or of very irregular shapes. The bubbles, as a rule, occupy about half the area of the cavities which contain them. Some of the bubbles are movable, but the great majority of them are stationary. Many of the lacunæ are full of liquid, whilst others contain gas, which in many cases has contracted on cooling. Some liquid cavities contain globules of liquid carbon dioxide with enclosed vacuum bubbles—bubbles within bubbles—the inner bubbles being movable and in some cases remarkably lively. There seems to be no doubt of the larger bubble being carbon dioxide, as the inner bubble disappears when a piece of heated iron is brought near it and re-appears on cooling.

The beryl also contains some good "stone cavities" with fixed bubbles, that is to say, enclosures in which a stony base has deposited crystalline matter on cooling.

Nos. 22 to 25.—Gneissose granite at Chora between Sarhan and Taranda, Sutlej valley. The extreme whiteness of the felspar is in strong contrast with the

blackness of the biotite, which is abundant. A parallelism of structure in the arrangement of the biotite is, to a certain extent, observable in the hand specimen.

M.—Orthoclase and quartz are probably about equal in amount; plagioclase is also present, but is subordinate; schorl is very abundant, it is in large irregularly shaped pieces, and encloses rather large grains of quartz. The slice also contains muscovite, biotite, and garnet. The biotite and muscovite are for the most part linked together in tortuous strings; leaves of the one occasionally alternating with the other species of mica: micro-garnets, and rounded microliths of biotite are scattered rather freely through the slice.

Gas cavities are abundant, and there are good liquid cavities with movable bubbles. The flat type of liquid cavities is also common.

The slice contains numerous stone enclosures that have deposited dusty matter on cooling. One of these, depicted at figure 5, has been fractured; the fractures being probably due to contraction on cooling, and the subsequent dislocation to a tremulous movement of the viscid matrix. In other cases, instances of which are depicted at figures 6 and 7, these stone enclosures, or crystals, have either deposited minute endo-crystals on cooling, or have in the process of their own crystallisation caught up previously formed microliths and held them in their embrace during consolidation.

In either case, the instauces illustrated at figs. 5, 6, and 7 show that the rock was, at one stage in its history, in a more or less liquid or fused condition.

At fig. 8 I have given another illustration from those slices, in which minute crystals are contained in another crystal, which is itself caught up in, or was deposited from, a stone enclosure.

The size of the bubbles in the liquid lacunæ relatively to the area of the cavities varies considerably, but I should think on the average the cavities cover an area of from two and a half to three times that of the bubbles.

Nos. 26 to 30.—Gneissose granite between Kalog and Báli, Sutlej valley. On the high level road, now fallen to ruin, between Nakanda and Rámpur.

M.—These slices contain some cavities that have deposited stony material, enclosures with fixed bubbles in them and microliths that contain cracks which have evidently resulted from shrinkage on cooling.

Nos. 31 to 33.—Gneissose granite from the Kot peak above the Bági road, described at Vol. X, p. 217, Records.

M.—This rock has all the appearance of a true granite under the microscope. Orthoclase and plagioclase are both present—the latter in some abundance. Biotite and muscovite are plentiful. Quartz is subordinate to the felspar.

Muscovite is present in the form of well-cleaved folia and also as microliths, the latter being very abundant. Biotite also occurs in large microscopic leaves grouped together, and in small rounded isolated ones of microscopic size scattered through the ground mass.

Long, attenuated, colourless microliths, often bent and broken, are present in considerable abundance, and appear to be imperfectly developed apatite.

Opacite occurs in some quantity; sometimes it is attached to microliths and at others is caught up inside them, in both cases being very similar to those described in my paper on the lavas of Aden. See figs. 4, 6, 11, 12, and 13 of the plate illustrating that paper. Records, Vol. XVI, p. 158.

Some microliths contain what appear to be shrinkage cavities and enclosed micro-crystals. One of the former is undoubtedly due to shrinkage on cooling, as it runs the length of the microlith and conforms to its shape. The illustration given at (*a*) of fig. 11 of the last-quoted paper applies equally to the microliths now described.

The quartz contains liquid cavities with movable bubbles, but they are not very abundant. It also contains elongated prismatic enclosures that have deposited dusty matter on cooling.

Slice 23 contains some minute prisms of schorl and some hæmatite or göthite.

Nos. 34 to 50.—Gneissose granite, Bági road. All that needs to be noted regarding these specimens is that they contain liquid cavities with movable bubbles, numerous microliths with fixed bubbles and elongated shrinkage cavities, running with the length of the microlith; and microliths cracked through shrinkage and fractured owing to a tremulous movement in the viscid matrix. These microliths have either caught up opacite at the time of formation or have deposited it on cooling, and they have opacite granules attached to them, in both cases resembling those described under Nos. 31 to 33, and which have been compared with similar bodies in the Aden lavas.

No. 51.—A dark porphyritic gneiss, from the flank of Hattu, between Hattu and Nakanda. There is a small outcrop at about the same elevation as the Nakanda travellers' bungalow. The gneiss contains small felspar "eyes" and large rectangular crystals of orthoclase.

M.—This is, I think, a metamorphic rock. It is composed of quartz in minute granules, orthoclase, a few crystals of plagioclase, and countless leaves of a dark greenish-brown mica. There is complete parallelism of structure, and all the leaves of mica not only point in the same direction, but their optical orientation is perfectly homogeneous, and when the slice is revolved under a single nicol, extinction is simultaneous in all the leaves.

Some colourless mica and some garnets are present, and countless crystals and granules of epidote. There are no liquid cavities with bubbles.

Nos. 52 and 53.—From the summit of Hattu. These specimens would, if their macroscopical appearance alone were considered, be classed as ordinary and very typical gneiss.[1]

The felspar is present in the form of eyes, and in elongated masses or strings of eyes, and occasionally in more rectangular crystals. Many of the eyes exhibit carlsbad twinning, the twinning plane coinciding with the longest diameter of the eye. The matrix is strongly foliated, lines of dark mica curving round the felspar crystals. The cleavage planes of the rock sparkle with minute facets of mica.

M.—Quartz predominates over the felspar and plagioclase is sparse. A large crystal of orthoclase is twinned on the carlsbad type, and in one twin an intergrowth of plagioclase has taken place.

The leaves of muscovite and biotite exhibit a strong tendency to arrange themselves in strings which flow round the porphyritic crystals. The leaves of biotite and muscovite in these chains often alternate with each other, at other

[1] Records, Vol. X, p. 217.

times part of a string is formed of leaves of biotite linked together, and the other portion of leaves of muscovite combined together. The leaves do not all follow each other in straight lines, but some radiate from the chain at high angles to it. Extinction does not take place simultaneously in all the leaves of biotite as in No. 51, but the greater proportion of the leaves in the field of the microscope extinguish together.

The mica is not confined to these strings, but is also scattered promiscuously through the slice, and there are many rounded and elongated microliths of biotite in the slice. Some other colourless microliths are also present, but they are not numerous.

The quartz is in minute grains, and a general parallelism in the arrangement of these grains is distinctly observable. Flat liquid cavities, with fixed bubbles, are rather numerous.

Liquid cavities, with movable bubbles, are abundant in some grains, but not in others.

Dendritical muscovite is plentiful in one of these slices.

Slice No. 52 contains some small colourless garnets.

I think this specimen is an ordinary gneiss.

Nos. 54 to 59.—Granite from the summit of the Chor mountain. A medium-grained granite, containing quartz, felspar, a dark mica, schorl, and some small garnets. Some of the larger orthoclase crystals are seen to be macled on the carlsbad type. The rock has a speckled appearance owing to the superficial decomposition of some of the felspar.

M.—It is not possible to determine the relative proportion of quartz to felspar from mere inspection, for in some slices quartz preponderates and in others felspar. A macroscopical examination of the hand specimen, moreover, does not enable me to decide the question. On the whole, I think, quartz and felspar are pretty equally divided.

Plagioclase is present in some abundance, but it is decidedly subordinate to orthoclase.

Fibrous felspar is to be seen in one of the slices, and it shades here and there into typical microcline.

Orthoclase is occasionally seen to be twinned on the carlsbad type, and one crystal of this mineral encloses a small prism of orthoclase macled on this system.

Muscovite is very sparse except in the form of microliths, but these are so abundant in some of the felspars as to make it almost impossible to say whether the latter are monoclinic or triclinic. Some cryptocrystalline mica is also present.

The biotite, in transmitted light, is of pale greenish-brown colour in sections that display the basal cleavage; whilst sections which coincide with the cleavage, *viz.*, those normal to the optic axis, are of deep rich reddish-brown.

Garnets, colourless in transmitted light, are rather numerous. They are for the most part of good size, and frequently present regular crystallographic outlines. The larger ones generally present six-sided sections, whilst some of the minute ones appear to be in the form depicted in figs. 241, 242, and 246, page 266, J. D. Dana's System of Mineralogy, *5th edition.*

Some of the slices contain patches of chloritic matter, which appears to be a secondary product resulting from the alteration of garnet. One patch is four-sided, the sides being straight lines, and is doubtless a pseudomorph after garnet; whilst, in other cases, small groups of garnets, some of which are in process of alteration, are embedded in chloritic matter, which, it seems probable, was formed from the degradation of some of the members of these groups. One of the garnets exhibits a feeble double refraction.

The slice is stained here and there with ferric oxide apparently derived from the biotite, and this imparts rather a pink appearance to the rock viewed macroscopically.

Two of the slices contain grains of magnetite either caught up in or adjoining leaves of biotite. I have several times seen the presence of magnetite fringing biotite or hornblende attributed to the decomposition of these minerals, but I do not think there are any grounds for supposing that the magnetite has been derived from the biotite in this case, for the grains of the former are of considerable size and the biotite exhibits no signs of alteration in their neighbourhood. I think the biotite was attracted to the magnetite, by molecular attraction, at the time of crytallisation and formed upon it. Magnetic attraction even might come into play between magnetite and a mineral so rich in iron as biotite.[1] In some specimens (J. D. Dana) the percentage rises as high as 26·9.

One piece of felspar contains a large prism of quartz with pyramidal terminations. The felspar itself is a very peculiar object. It is traversed in parts by irregular straight lines running in one direction that polarise in a different tint to the body of the felspar. They are very fine lines with rather jagged sides, and they want the regularity of plagioclase twinning. Some of them are long and some of them are short; some bifurcate towards their termination, others inosculate with each other. These lines are traversed at a low angle by another set of larger and still more irregular lines, or veins, which here and there merge into the first set. The second set of lines is filled in part with cryptocrystalline mica, and in part with felspar. At their terminal ends they merge into patches of cryptocrystalline or dendritic mica. It is difficult to say whether the two sets of lines are due to intergrowth, or to cracks formed along intersecting cleavage lines before the whole of the mineral constituents of the rock had completely consolidated. Such cracking might easily occur in a viscid or partially consolidated rock subjected to great strain in the course of intrusion into hard stratified rocks, and I think the appearances above described are probably due to this cause. Other felspars appear also to have been cracked, and filled with a confusedly crystalline material which seems to be in part micaceous.

The quartz is in large and also in microscopic grains; liquid cavities with movable bubbles are not numerous, and they are of minute size; cavities with fixed bubbles containing a coloured liquid, or glass, are not uncommon. Hair-like belonites are numerous in the quartz.

"Stone enclosures," or microliths, that have deposited minerals on cooling, occur in these slices. A sketch of one is given at fig. 1. The crystal deposited

[1] Electro-magnets are now used in chemical laboratories to separate minerals rich in iron from those poor in iron.

at (*a*) has curved sides suggestive of siderite. Other crystals have been had deposited at (*b*). The microlith has cracked in two places, probably the result of contraction on cooling, and one crack has resulted, apparently, in its division into two pieces.

At figs. 2, 3, and 4, I have depicted illustrations, taken from these slices, of opacite (apparently magnetite) deposited in cavities. It is difficult to say whether the opacite was deposited on cooling from a glass which, when under high pressure, at a great heat, held it in suspension, or whether the glass was attracted to the opacite. Figs. 2 and 3 seem to me instances of the former; but whichever explanation be the true one, in either case the rock must have been in a fluid or semi-fluid state; and cases such as those depicted in figs. 1 to 4 seem to indicate that the rock, before consolidation, was in a condition of *aqueo-igneous* fusion.

No. 60.—From the crest of the ridge of the Chor mountain above Barela. This is seen to be composed of quartz, felspar, and black mica (biotite). Some of the felspars are in large porphyritic crystals. The mica is embedded in the felspar and quartz, but it principally flows in streams round the felspar crystals and gives a gneissic aspect to the rock.

M.—The quartz is in small grains with the meandering irregular outlines characteristic of the quartz of granite. It is also present in the form of micro-crystals. Orthoclase is abundant and the slice contains a large carlsbad twin. Plagioclase is plentiful, but it is very subordinate to the orthoclase. Biotite is abundant in large and in micro leaves. Muscovite is present, but sparsely so. Rounded garnets are numerous and one of them is embedded in biotite.

A cluster of epidote grains occurs in a triclinic felspar, and a few other grains are scattered about in the slice.

The felspar alluded to contains multitudes of microliths, some long and hair-like, others of somewhat stout build. Some of them apparently deposited mineral matter on cooling. Fig. 21 is an illustration of one of them.

The quartz contains numerous liquid cavities with good-sized bubbles. I have not observed movement in any of them. Gas cavities are not uncommon, and enclosures containing a coloured liquid, or glass, with fixed bubbles, similar to those in the specimen from the top of the Chor, occur in this slice also.

Nos. 61 and 62.—A felspathic schist from the vicinity of Barela. The specimen was taken from a bed below the outcrop of the gneissose granite.

M.—Under the microscope this specimen resembles a micro-gneiss. Grains, or eyes of felspar and quartz, are arranged in approximately parallel lines, the intervals between them being filled up with micro-grains of quartz and minute leaves of a brown-green mica. The felspar is principally orthoclase—a little of it is plagioclase. In one slice the felspar and quartz are eye-shaped, in the other they have the appearance of sub-angular and rounded grains.

The mica is in minute leaves. No basal cleavage is anywhere to be seen, and in one slide it is only dichroic here and there, showing that the leaves are all turned one way so as to present axial sections.

This is unquestionably a clastic rock, though whether it is a micro-gneiss, properly speaking, or whether it is a somewhat altered sandstone, made up of granitic or gneissic materials, is more difficult to determine.

The quartz is not at all hyaline, and I have detected no liquid cavities in it.

No. 63.—From the Chor mountain near Tálichog. This is a very dark specimen owing to the abundance of black mica. The hand specimen contains rectangular porphyritic crystals of felspar, one of which is $2\frac{5}{8}$ inches long by $1\frac{1}{4}$ inches wide. Two adjoining ones are twinned. In one or two places the quartz and biotite have formed streaky-looking combinations.

M.—This generally resembles No. 60 from Barela. Orthoclase predominates over plagioclase, and felspar over quartz. Garnets are numerous, and epidote is more abundant than in No. 60. Both occur enclosed in biotite and also separately. Epidote is commonly found in syenite, and it is supposed to be the alteration product of hornblende. I have not as yet found any hornblende in these rocks.

There are nests of colourless microliths, some of which may be apatite; cracks, apparently due to shrinkage, are very common in them. Some few have deposited mineral matter on cooling, or have caught up such matter in the act of consolidation.

Liquid cavities with movable bubbles are sparse.

The outer band at Dalhousie.

The following specimens were examined, namely:—

Nos. 1, 2, 3, 4, 5, and 6, from the neighbourhood of Bagrár (Bagraur), from the vicinity of Banatu (trans-Ravi), and from the ascent between Sherpur (Sairpur) and Dalhousie.

Nos. 7, 8, and 9, from the cart road near Dunhára (Daniara).

Nos. 10, 11, and 12, from below Bátri (Rampur of the map).

Nos. 13 and 14 from Chuári (Chaohari).

Viewed macroscopically, Nos. 1 to 6 and 10 and 11 would be classed as streaky gneisses; 7, 8, 9, and 12, as gneiss verging towards the granitoid type. 13 and 14 are porphyritic gneisses, inclining towards granitoid gneiss. The porphyritic crystals are rectangular, and are oriented at varying angles to the line of pseudo-foliation.

I now proceed to give an account of the structure of these specimens as exhibited by thin slices under the microscope.

All the specimens contain quartz. In some slices the quartz predominates over the felspar; in others the latter is in the ascendancy. On the whole, quartz is probably somewhat more abundant than felspar.

Nearly all the quartz is in the form of fish roe grains, similar to that described in my paper on the gneissose-granite of Dalhousie. It meanders through the slice in strings, and fills cracks in felspar crystals. The grains are extremely minute and frequently show a tendency to hexagonal outlines.

Orthoclase is present in all the slices, and microcline is observable in slices Nos. 8, 10, 12, 13, and 14; being plentiful in No. 12, but not abundant in the others.

Plagioclase is absent in Nos. 2, 4, and 6; plentiful in No. 12, but sparse in the remaining slices. Orthoclase, therefore, largely predominates over triclinic felspar.

Biotite is present in Nos. 7, 8, 9, 10, 11, 13, and 14, and a mica, dark green in transmitted light, that is probably biotite, is present in the rest

Muscovite is present in all the slices, and it occurs both in its foliated form and as microliths. In No. 4, the latter are so abundant in some of the felspars as to nearly overpower the felspathic element and to give the felspars superficially a micro-felsitic aspect.

Cryptocrystalline mica occurs in all the specimens, and is plentiful in some slices. It is drawn out into strings, and meanders about in a stream-like course, in the manner described in my paper on the gneissose granite of Dalhousie.

Magnetite, ferrite, and garnets, are to be found in all; whilst schorl is abundant in No. 12, but absent from the other slices.

Liquid cavities with movable bubbles are present in all, except Nos. 8, 9, 10, and 11. They are of good size in Nos. 4 and 5, but are generally very minute in the remaining slices. They are very numerous in Nos. 4, 5, 7, 12, and 14, but are somewhat sparse in the others. In No. 12 they are not only abundant in the quartz, but are almost equally so in the felspar and schorl: a large garnet is also full of them. The cavities and bubbles in the schorl and garnet are relatively much larger than those in the quartz and felspar, and would seem to indicate that the schorl and garnet crystallised at an earlier stage of consolidation of the rock than the felspar and quartz. In this slice, even a microlith of muscovite contains liquid cavities with movable bubbles. In No. 14 a microlith contains seven cavities with fixed bubbles, which appear to be liquid cavities. If these are glass cavities, they would afford a strong argument in favour of the igneous origin of the rock; but even on the supposition that they are liquid cavities, the presence of numerous liquid cavities crowded into a minute microlith indicates that, when the latter consolidated, the rock must have been in a fused or plastic condition, and the intermixture of super-heated water or steam with the mineral constituents of the rock most intimate. We have already seen that when the beryl of the Wangtu eruptive granite crystallised, the granite was in a similar condition. A sketch of this microlith (much enlarged) is given at fig. 20. It reminds one very much of the microlith figured at fig. 11, taken from Jángi granite. Air or gas enclosures are present in all the slices, and are sometimes abundant.

I now proceed to note some points of special interest observed in the several slices.

In No. 1, the twinning planes of the plagioclase are sometimes very much bent out of the perpendicular, showing that they were subjected to considerable strain between the time of their crystallisation and their attainment of perfect rigidity. A similar feature is observable in some of the other slices.

At fig. 15 (*a*) I have given a sketch of a crumpled mica seen in slice No. 7, which appears to have been doubled up after crystallisation, whilst the laminæ were still pliant, in the manner described in my paper on the gneissose granite of Dalhousie (see fig. 4, plate II, of that paper). In that paper, I attributed the crumpling to traction.

The mica is muscovite, (*a*) the substance in which it is embedded is a structureless, whitish, opaque substance, analogous to leucoxene: (*b*), in the illustration, is the termination of a long string of fish roe quartz.

At fig. 14 I have given a sketch, taken from slice No. 1, in illustration of a peculiarity characteristic of these rocks; (*a*) is a narrow stream of leucoxene,

or allied substance, white in reflected, but perfectly opaque in transmitted, light. The dark line (*b*) that runs along the lower border of the leucoxene is red ferrite: (*c*) is a train of magnetite, or ilmenite grains, in the stream of leucoxene: and (*d*) is a garnet. The ferrite, it will be observed, does not come into contact with the grains of magnetite or ilmenite. I do not think that the leucoxene has been produced by the decomposition, *in situ*, of the iron grains, for several reasons. In the first place, the grains of magnetite do not show any trace of decomposition along their edges, but are perfectly fresh throughout. Secondly, grains of magnetite are to be seen in other places quite unconnected with the leucoxene; whilst streams of the latter substance are common between which and the iron no direct connection can be traced. The ferrite, on the other hand, is often directly connected with magnetite. The explanation of the above facts appears to me to be as follows: when the plastic rock was at rest, the acid and aqueous vapours contained in it began to act on the iron, and leucoxene was formed by the action of the former on the ilmenite, and ferrite by the action of the latter on the magnetite. Motion succeeded to the temporary rest, and then the leucoxene and ferrite were, under the influence of traction, drawn out into strings in which the undissolved fragments of ilmenite and magnetite were frequently entangled.

This explanation, of course, involves the supposition that the iron first crystallised and was afterwards acted on by the corroding action of acid vapours contained in the rock; but this suggestion will present no difficulty to those who have studied, under the microscope, such volcanic rocks as the dolerite of Auvergne, in which the corroding action of vapours on some of the minerals contained in the lava is frequently to be observed.

Since writing the above lines, I have come across an interesting remark regarding ferrite in Mr. J. J. Harris Teall's Cheviot Andesites and Porphyrites (Geological Magazine, Decade II, Vol. X, p. 257). In describing a porphyrite showing "well-marked fluidal structure," he remarks: "The ferrite is especially abundant in fluidal bands and stripes which curve round the larger crystals in a very characteristic manner. Vogelsang describes a similar distribution of ferrite in certain of the Hungarian quartz-trachytes."

The above fact that ferrite has been observed drawn out in "fluidal bands and stripes" in true lavas by competent observers, affords an important confirmation of the conclusion I independently arrived at regarding the origin and significance of the ferrite "bands and stripes" in the rock under consideration.

The felspars (orthoclase) in these slices sometimes contain intergrowths after the manner of perthite. In some cases the mineral intergrown with it is felspar, at other times quartz.

Cracks in felspars filled up with fish roe quartz are very common, whilst occasionally the latter appears to be the residuum, left in pools, so to speak, in the interior of felspars, after the separation of the alumina and the other constituents of the felspar.

At fig. 16 I have given a sketch, taken from slice No. 6, of what appears to have been a large felspar, cracked and split into pieces and then pushed over like books on a shelf by pressure and traction. At any rate the outlines certainly suggest this idea. The cracks are filled partly with fish roe quartz, but principally by cryptocrystalline mica. The dark portion at the bottom

consists of dark micaceous, imperfectly crystallised matter, running in ropy lines through the slice. The several pieces of felspar shown in the sketch are all in optical continuity with each other, and appear to be fragments of one crystal.

At fig. 18 I have represented a minute stone cavity, found in slice No. 6, in which crystalline matter has been deposited on cooling. The upper mineral has a distinctly hexagonal form, whilst the lower mass seems to be an agglomeration of stony matter rather than one crystal. Forms such as these show distinctly that the mass in which they are found was reduced to a fused or plastic condition by heat.

At fig. 17 I have depicted a cavity, seen in the same slice (No. 6), which contains a large air-bubble. The cavity was evidently once filled with air, to the expansive power of which the formation of the cavity is due, but the air contracted on cooling to its present size. The bubble, as will be seen in the sketch, seems to be a little too wide for the cavity; this appearance, however, is simply due to refraction, the empty portion of the cavity acting on the light passing through the mineral differently from the bubble of air.

Fig. 19 is another illustration of the same kind taken from slice No. 12. The cavity is in a schorl crystal, and contains air or gas that has contracted on cooling. The bubble does not contain the central transparency usually seen in air bubbles, but it shines brilliantly in reflected light like an air or gas bubble.

These cavities and contained air or gas bubbles—and they are by no means the only examples of the same kind contained in the slices under description—afford evidence to show that these rocks were subjected to sufficient heat to reduce them to a plastic condition. The bubbles on cooling appear to have contracted to about half their original size, from which I infer that the rock was raised to a high temperature. The fact that the cavities themselves are not circular, is explained by the fact that their shape is controlled by extraneous forces, and among others the crystallographic energy of the molecules of the mineral in which the cavity is formed, air or gas caught up by a mineral in the act of crystallisation would expand, not equally in all directions, but along the lines of least resistance which would usually coincide with the cleavage planes of the crystallising mineral.

Conclusion.—The rock specimens described in this paper come from an extended area. The first is that of granite intrusive in mica schists above Darwás, in the Pángi valley of Chamba; the next is granite intrusive in the schists at Leo, on the Spiti river. Other specimens are from the cliffs above Jángi, in Bassáhir, on the Upper Sutlej, and from dykes at and near Rarang and Pángi, in Bassáhir.[1]

There can be no doubt whatever of the eruptive character of these granites, for they are seen in the field to cut across the schists, and in some cases to penetrate them in all directions. I thought, therefore, that they would be good rocks to compare with the gneissose granites of neighbouring regions.

Following the line of the Sutlej river, I collected my other specimens at Wangtu, at Chora, at the Kot peak and the Bági road, at Báli, and at the Hattu mountain above Nákanda, in the neighbourhood of Simla. I then passed to the

[1] Chamba Pángi is on the River Ravi; Bassáhir Pángi is on the Sutlej.

Chor, a prominent mountain abutting on the plains; and, finally, I came to the outer band of gneissose granite at Dalhousie.

The granite from the dyke that bursts across the schists above Darwás (slice 1) is interesting, from the fact that, when viewed macroscopically, it exhibits some slight traces of incipient parallelism of structure due to traction. It possesses no other structural peculiarity worth noting. The latter fact, I may remark in passing, shows that when examining a single slice of a granitic rock under the microscope, with a view to determining whether it is of eruptive or metamorphic origin, mere negative evidence is not of much value.

The Leo granite has several points worthy of consideration. Nearly all the quartz in it is of polysynthetic structure, similar to the fish roe quartz of the Dalhousie gneissose granite; and this shows that the conclusion which I arrived at in respect of the latter—namely, that the fish roe grains do not indicate a clastic origin [1]—was sound.

Another point to be noted is that liquid cavities with movable bubbles are not very abundant in the Leo granite. Liquid cavities may be abundant in some parts of a granite and not in others; their sparseness, or even absence in a single *slice*, therefore, is of little importance in determining the igneous or metamorphic origin of a rock.[2]

Evidences of strain are seen in the Leo granite in the curvature of the twinning planes and the cracking of felspar crystals.

The muscovite of this granite polarises in delicate colours, but with extreme brilliancy, precisely as it does in the gneissose granites; the dullness of the muscovite of the Durwás and Pángi specimens, under the polariscope, does not therefore indicate any structural or varietal difference dependent on their mode of origin. Both the Leo and Darwás specimens are from dykes intrusive in schists.

In No. 3, garnets and schorl are drawn out into strings—an indication, I think, of traction.

The biotite in such rocks as the Jángi granite (Nos. 5—12) may be usefully compared with the dark mica in such rocks as the gneiss of Hattu (Nos. 51—53) and of Barela (Nos. 61 and 62). In the former, the basal cleavage of the mica is well developed, the folia are oriented in all directions, and the biotite embraces garnets or other minerals. In the gneiss alluded to, on the other hand, the dark mica is in minute scales which do not exhibit any basal cleavage; moreover, when slices of the gneiss are revolved over the analyser, the mica either fails to exhibit dichroism at all, owing to all the leaves being axial sections, or extinction takes place simultaneously in the whole, or in the majority of the leaves; an indication in both cases that the scales of mica are all in the same plane,—a fact that points to a metamorphic or clastic rather than to an igneous origin.

[1] Records, Vol. XVI, p. 130.

[2] To prevent any misapprehension of my meaning I may add that though the abundance of liquid cavities with movable bubbles is very characteristic of a plutonic eruptive rock—see remarks *ante* on the Wangtu beryl—liquid cavities are also to be found in some metamorphic rocks, as will be shown in my next paper.

"Stone enclosures," which contain endo-minerals, gas, and lacunæ with fixed bubbles in them (figs. 11—13), are to be seen in the Jángi granite.

These stone enclosures afford good evidence of the rock which contains them having been subjected to great heat and of having been reduced to a more or less fluid or plastic condition; and they are useful for comparison with similar bodies formed in the gneissose granite.

In the granite from the dyke that bursts through stratified rock at Rárang, a parallelism in the arrangements of the biotite resembling incipient foliation is to a limited extent observable on a macroscopic inspection.

In the Pángi granites liquid cavities are very numerous, and the bubbles are of large size relative to the area of the enclosures containing them. This indicates that the rock was subjected to great heat and pressure; whilst the perfectly crystalline condition of these rocks shows that they were in a fused or fluid condition and cooled slowly.

A little microcline is present in the Pángi granite (14) and it is abundant in the Wangtu granite (20, 21).

I now pass from granites proper to the gneissose granites, or what used to be called the granitoid gneisses of the Sutlej valley.

In mineral composition these rocks do not materially differ from those of the granite group above alluded to. Both classes contain quartz, orthoclase, plagioclase, microcline, biotite, muscovite, schorl, garnets, and magnetite.

With the exception of beryl and kyanite in the neighbourhood of Wangtu, and epidote and chlorite in some of the Chor specimens, I have not found any other minerals in the samples examined.

In the gneissose-granite of Chora stone cavities or crystals, containing endo-crystals and enclosures (figs. 5—8) of the same class as those found in the granites proper (figures 9—13) were found. In fig. 11 (Jángi granite) the microlith is severed by a crack, apparently the result of shrinkage. In fig. 5 (gneissose granite) the microlith is cracked in two places and dislocation has resulted owing probably to a tremulous movement passing through the viscid matrix.

The gneissose granite of the Chor mountain contains a good-sized prism of quartz, with pyramidal terminations caught up in a large piece of felspar. This seems to indicate a more or less fluid stage in which the quartz prism had time to form free from any excessive pressure from the surrounding felspar.

Stone cavities, similar to those found in the granites, which have deposited endo-crystals, or mineral matter, occur in the Chor rocks, and illustrations of these bodies are given at figs. 1—4 and 21.

These rocks also contain coloured liquid or stony enclosures with fixed bubbles, and microliths that have cracked, apparently from shrinkage on cooling.

I think the rocks which I have classed, in the above pages, as gneissose granites, afford under the microscope the same kind of evidence, and as good evidence, of having passed through a stage of *aqueo-igneous* fusion as the undoubtedly intrusive granites.

The further fact that they have been in motion has been established for the exactly similar rocks of the Dalhousie area; and I hope in a subsequent paper

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train of magnetite or ilmenite fragments entangled in a stream of leucoxene, and I have given my reasons in the preceding pages for believing that the leucoxene was not derived from the decomposition of the magnetite or ilmenite *in situ.*

At fig. 18 a "stone cavity" which has deposited crystalline matter on cooling, taken from slice No. 6, is represented, which will bear comparison with similar bodies found in the Aden lavas, and represented at figs. 4, 5, and 6 of the plate which illustrates my paper on those rocks. (Records, Vol. XV., p. 159.)

At figs. 17 and 19 (the latter is enclosed in a schorl crystal), I have sketched cavities containing air or gas bubbles, which have contracted subsequent to the consolidation of the rock, and now imperfectly fill the cavities which doubtless they once fully occupied, when expanded under the influence of heat.

The facts stated above appear to me to prove that the rock under examination was subjected to great heat; that it passed through a stage of aqueo-igneous fusion, and that before its complete solidification it was subjected to great strain and pressure.

If the inferences I have drawn from the train of magnetite or ilmenite fragments in the train of leucoxene, and from the presence of a crumpled mica, are sound, it also follows that the rock, or portions of it, were in motion.

The mere fact that the rock, or a portion of it, was in motion does not, of course, prove its eruptive character. Great pressure, exerted on sedimentary or metamorphic rocks, may result in motion; as, for instance, the cases in which limestones under the influence of great pressure imitate eruptive rocks and become intrusive in others. But in the case of the Dalhousie "outer band" the whole rock has evidently been in a condition of igneo-aqueous fusion, and evidence of motion in such a rock acquires additional importance.

If we take all these facts into consideration, together with the further fact that in mineralogical composition the rock under consideration is identical with that of the neighbouring gneissose granite, which has been shown to be an eruptive rock, may we not fairly conclude that both rocks have the same origin, and that the structural difference between them, which is one of degree only, is due to the outer band having been intruded as a sheet between hard strata, or forced between the walls of a fault in a viscid or partially consolidated condition, and subjected to great pressure and squeezing at right angles to the direction of the flow? I think myself this is a reasonable inference to draw from the evidence.

It is clear, as shown in the preceding pages, that the "outer band" has passed through a stage of aqueo-igneous fusion. On the other hand, I do not think that great heat is required to explain the metamorphism of the schists in contact with the "outer band" along its northern boundary—the passage of moderately-heated water through slates seems to be all that is necessary to account for the production of micas of the class to which those in these schists belong.

In a recent tour, the results of which I hope to publish in a future paper, I found highly micaceous slates, that might be classed fairly as mica schists, intercalated between perfectly unaltered dark-blue carbo-triassic limestones—a circumstance by no means puzzling when we know that certain micas—all the hydromicas probably—can be produced through the agency of moderately-heated water.

On the whole, then, I think there are good grounds for assigning a different origin for the "outer band" and for the schistose rocks in contact with it.

The conclusion at which I have arrived, on a consideration of all the facts of the case, is that the invasion of previously metamorphosed strata by gneissose granite, combined with the pseudo-foliation of the latter due to the pressure of hard strata on a partially cooled and imperfectly viscid rock, has imparted to the intruded rock the superficial appearance of being a member of the same metamorphic series as the schists and slates into which it has intruded.

There is no inconsistency, I would point out in conclusion, in supposing that the rock which gives evidence of having passed through a stage of aqueo-igneous fusion was partially cooled and semi-viscid where actually intruded into the schists. Observation in our own time shows that there are pauses and long intervals in volcanic action; and doubtless similar pauses took place in plutonic action during which the cooling and partial consolidation of igneous masses went on and the large porphyritic crystals found in many of them were formed. The subsequent motion of a partially consolidated viscid rock and its intrusion as a sheet between hard strata, or between the walls of a fault, would, it seems to me, naturally produce a parallelism of structure, or pseudo-foliation, as long ago pointed out by Scrope and Naumann.[1]

The "outer band" of Dalhousie seems, in some respects, to be analogous to granulite (leptynite), a foliated rock associated with gneiss and other crystalline rocks in Saxony, Bohemia, and Moravia, which is classed as eruptive by Naumann, M. M. Fouqué and Michel Lévy, and other petrographers.[2]

The mica of granulite appears to be at times disposed "in scaly seams entirely dividing the rock," a marked characteristic of the "outer band" of the Dalhousie gneissose granite.

DESCRIPTION OF THE PLATE.

Fig. 1.—Stone cavity, or microlith, in the gneissose granite of the Chor, which has deposited crystals on cooling. Taken from slices 59—64.

Figs. 2, 3, and 4.—Opacite, probably magnetite, deposited in cavities. Chor gneissose granite. Slices 59—64.

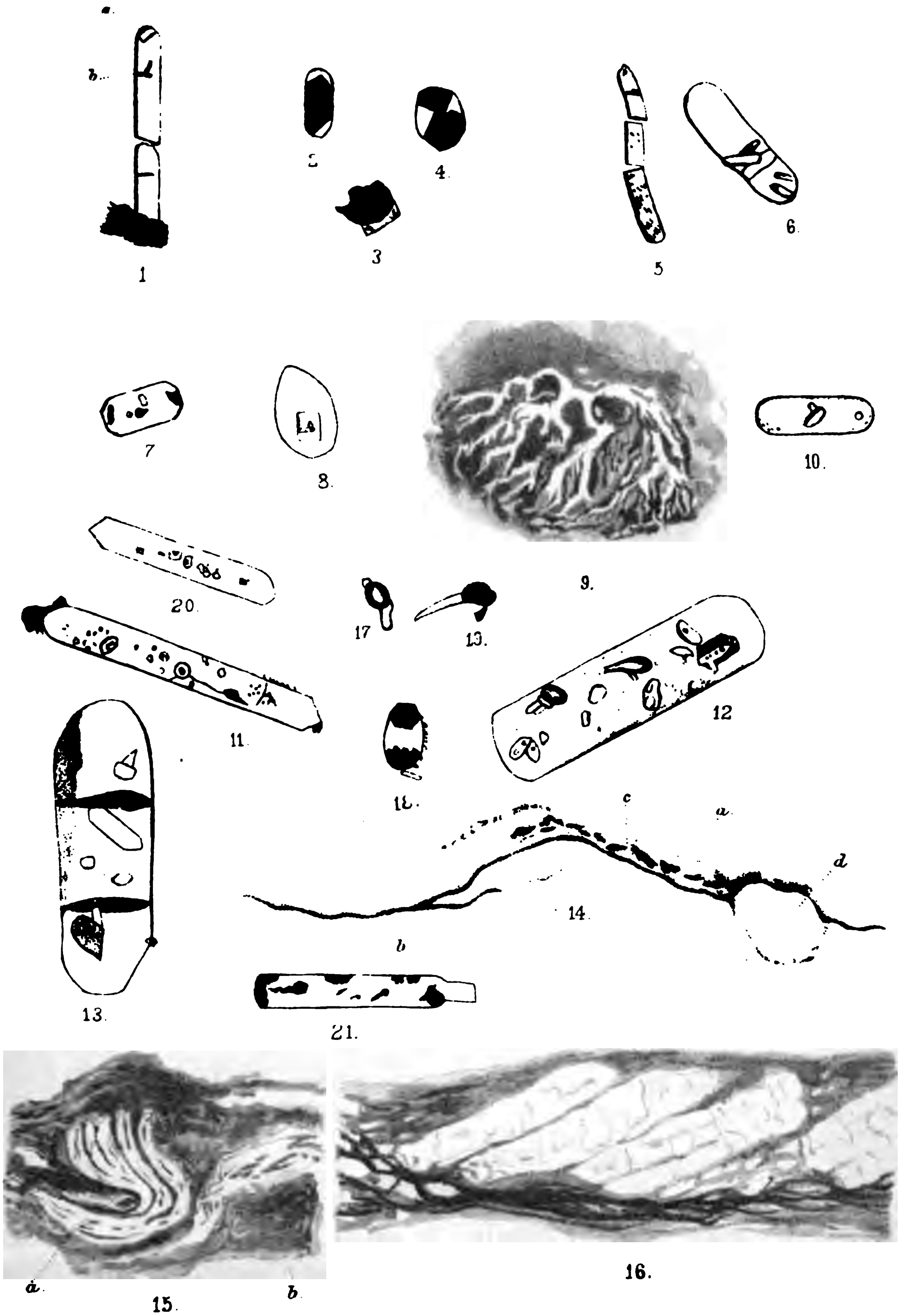
Figs. 5, 6, 7, and 8.—Illustrations of stone enclosures, in which mineral bodies, enclosed in the gneissose granite of Chora, have either deposited minute crystals on cooling, or have, in the process of their own crystallisation, caught up previously formed microliths. Slices 22—25.

Fig. 9.—Dendritic combinations of muscovite, microliths, gneissose granite, Wangtu, Sutlej valley. Slices 16—19.

Figs. 10, 11, 12, and 13.—Stone cavities containing crystals and internal cavities with contraction bubbles. Granite, Jángi, Sutlej valley. Slices Nos. 5—12.

[1] See Scrope, Q. J. G. S., Vol. XII, p. 346. And his work on Volcanoes, pp. 103, 144—202. Naumann "On the probable eruptive origin of several kinds of gneiss and gneiss-granite." Q. J. G. S., Vol. IV. Translations and Notices of Geological Memoirs, p. 1.

[2] Geikie's Text-Book of Geology, p. 124. Cotta's Rocks classified and described, p. 221. Minéralogie Micrographique, par M. M. Fouqué et Michael Lévy, p. 174.



J. Schaumburg, Lith.[d] Printed at Geol. Survey Office.

Fig. 14.—Strings of red ferrite and a white substance resembling leucoxene in which fragments of magnetite or ilmenite are entangled. Outer band of gneissose granite, Dalhousie. Slice No. 1.

Fig. 15.—Crumpled mica. Outer band, Dalhousie. Slice No. 7.

Fig. 16.—A large felspar, cracked, split into pieces and pushed over as books on a shelf. Outer band. Slice No. 6.

Figs. 17 and 19.—Cavities containing air, or gas, that has contracted on cooling. Outer band, Dalhousie. Slices 6 and 12.

Fig. 18.—Stone cavity in which mineral matter has been deposited on cooling. Outer band, Dalhousie. Slice No. 6.

Fig. 20.—Microlith containing lacunæ with fixed bubbles. Outer band, Dalhousie. Slice No. 14.

Fig. 21.—Microlith that has deposited mineral matter on cooling. Gneissose granite, Chor. Slice No. 65.

Report on the Choi Coal Exploration,[1] *by* G. F. SCOTT, M.E. (With a map.)

In this report I purpose to take each place separately and treat of its coal prospects.

No. 1. Choi, marked A on plan.

The coal here lies at the base of the hills; it had been worked previous to my arrival by means of headings driven in the hill-side and pits; there is hardly any coal left, nearly all having been worked.

A boring marked B on plan was put down to the depth of 80′ by Mr. Craythorne, but without success; it is evident that no regular seam of coal occurs, the quantity previously extracted lying in pockets. The strata are very contorted, and I question much, if coal were found, whether it would pay the cost of labour. Near the village, and along the Chablowala nuddy indications in the shape of black earth, and shale appear, but nothing substantial enough to guarantee a trial.

No. 2. Between Choi and Mungi, marked C on plan.

Leaving Choi and proceeding eastwards, the outcrop is seen on the side of the main road, and also down the hill, further east, I put down a boring marked C on the plan. On reaching limestone, I stopped the boring and commenced sinking to the black shale met with at the depth of 32′ 4″. From here a heading was driven in the direction of the dip of the coal (which is almost perpendicular), but when it had been driven 8 yards the coaly shale thinned out; another heading was driven, but that also for the same reason was abandoned. No actual seam was met with, the black shale that was followed had small parti-

[1] The exploration described in this report was suggested and carried out by the Department of Public Works. In order that so searching a trial of the ground may not be lost sight of, the account of it is appropriately published in these Records. The locality is in the Chita range, ten miles south of Attock. A general description of the ground by Mr. Wynne was published in 1877, Records, Vol. X, p. 107. The pseudo-coal-measures are those near the base of the nummulitic series which have so often raised sanguine expectations of coal in the North-West Punjab.—H. B. M.

cles of bright coal in it, but this, as was observed above, gradually thinned out to nothing. It is evident, therefore, that here and in the immediate neighbourhood where more indications are to be seen, there is not the slightest hope of any workable coal being found.

Indications of coal crop out here and there along the foot of the hills, until the place marked D on plan is reached. Here coal has been extracted by means of headings and pits; the latter are mostly full of water, so that the galleries underneath cannot be inspected; it is evident, however, from the headings that there is very little coal remaining.

No. 3.
Boring at Mungi, marked D on plan.

I put down a boring to the north of the previous workings; after a depth of 11′ 4″ limestone was reached; the boring was continued in this strata to the depth of 57′; the progress being slow, and there not being the slightest chance of striking coal, it was abandoned.

There is nothing here to tempt another trial, the quantity of coal that may be left being very small.

The outcrop continues almost in a straight line to the east. To test the strata a boring was put down at the place marked E on plan. It will be seen, on referring to the account of the boring, that up to date no seam has been struck, although a depth of 100 feet has been reached. The boring is still proceeding, but I am afraid it will meet with no success.

No. 4.
Boring east of Mungi, marked E on plan.

Leaving the hills, I thought, in order to thoroughly test the locality, that a couple of deep borings should be put down in the plain where it is evident the strata lie more horizontally. Accordingly, a boring was started at the place marked F on plan. After meeting with great difficulties the strata have been bored through nearly to the depth of 200 feet, and by referring to the account, there does not seem much likelihood of meeting with success. The boring is now in stiff blue clay, and probably limestone will be met underneath; should this occur it will be useless to proceed further.

No. 5.
Boring near Haro, maked F on plan.

A boring was commenced here intended to be as deep as the other, but at the depth of 55 feet an unexpected bed of sand and pebbles was encountered. All the boring pipes being required near the Haro, it was abandoned. Should, however, the present boring prove successful, it will be easy enough to start this one.

No. 6.
Boring at Dheri Khot, marked G on plan.

Traces of coal having been discovered between Choi and Bagh Nilab, I thought it would be as well to put down a trial pit. On the 14th April it was commenced, and at the depth of 15 feet a heading was driven at an inclination of 1 in 3. Up to date, nothing substantial has been found, although black shale bands occur with particles of bright coal in them. I do not think it probable that a seam lies here, but very likely a small quantity of coal, similar in nature to that at Choi, may be extracted.

No. 7.
West of Choi, not marked on map.

Between here and Bagh Nilab no indication of coal is found; at the latter place there are slight traces, but nothing sufficient to guarantee a trial.

Summary.

From what I have seen of this district, and from the several borings, the conclusion I have come to is, that the prospects of finding any sufficient quantity of workable coal either at Choi, Mungi, or the country lying to the west and east respectively, is very slight.

The coal itself is of a poor quality and resembles black shale more than anything else; it seems to be a good gas producer, and that is all that can be said in its favour.

The only chance of making this exploration a success has been tried,—that is, boring in the plain; had coal been struck, the seam would have lain at a more convenient angle, and there is no doubt but that there would have been a vast quantity of coal to work.

It is very evident that no seam lies in the hills, and, with the exception of Choi and Mungi, no coal has been worked, although trials have been made in various localities; it is almost conclusive, therefore, that the coal lies in pockets, and to work this seems to me to be far too speculative.

From J. T. O'CALLAGHAN, Esq., *Engineer-in-Chief, Punjab Northern State Railway, Northern Section, to the Director General of Railways,—No. 1335, dated 17th May 1883.*

I have the honour to forward herewith a report with plans on the search for coals in the Kala Chitta range of hills south of Attock carried out under the instructions conveyed in your No. 622 C of 16th November 1882.

Mr. Scott's report confirms the opinion I had already given in my No. 4074 of 22nd October 1880, to your address, and also the published opinion of the officers of the Geological Department.

While Mr. Scott was carrying out his exploration, I visited the district and went with him over most of the places where any indications of coaly matter appeared. The Kala Chitta range of hills consists almost altogether of grey nummulitic limestone, the beds of which are much contorted and are traversed by many faults. Near Choi the beds are tilted nearly vertical, and between two of the beds is a bed of brownish shale from 40 to 50 feet in thickness. This shale bed is traceable for some miles in an easterly direction from Choi, and at intervals in it pockets of black coaly shale are found. The pockets are lenticular in form and of no great extent in any direction, and when excavated have always died out within 40 or 50 feet of the surface of the ground. The so-called coal when excavated has also proved to be of little value as a fuel. It was of service in burning lime and keeping down the price of wood at a time when all prices had a tendency to undue inflation. But the attempts to make it into patent fuel fit for locomotive purpose has been a complete failure, the heat given out being much inferior to that obtained from an equal quantity of wood fuel.

In my opinion, any hope of procuring coal in the Kala Chitta range may be abandoned now and for ever. Had there been any appearance of a continuous seam of even the coaly shale found, deeper workings in it might have shown a better quality to exist below, but there is no continuity or regularity in the recurrence of these pockets, and the fine vertical section of the whole range of

hills which is made visible in the channel cut by the River Indus, shows that the great disturbance of the whole formation of these hills must preclude all hopes of horizontal beds of any kinds being found—see also opinion of Superintendent, Geological Survey, expressed in his letter No. 255, dated 29th September 1880.

What grounds Mr. Johnson had for the statement made in his No. 2845, 12th August 1882, to the Secretary to Government, Punjab, paragraph 5, that "the pocket theory was found to be erroneous, the so-called 'pockets' connect with each other and develope into seams, while the coal improves immensely in quality as the depth of the pits increased," I am at a loss to imagine. In no case has any pocket been found to extend into a seam, and without exception they have worked out in every direction in which they have been tried; and when last at Choi Mr. Johnson was unable to point out any continuous seam or to give any data on which his very sanguine report could have been founded. I can only infer that Mr. Johnson based his report on information received from a man named Craythorne, the practical miner referred to in paragraph 6 of his report. This man was originally a soldier in the 44th Regiment, and was taken from the regiment to work in the Warora Mines in 1874 or 1875, which situation he left and wandered up-country in search of work. His employment by the Executive Engineer was allowed, to assist in procuring fuel, and it was of course to his interest to make favourable reports in order that his employment might be continued. He absconded from Choi a short time before Mr. Scott's appointment.

The boring marked F is still continued and sandstone under the blue clay is reported, but this is probably only one of the thin beds of sandstone everywhere seen in the recent deposits through which the Haro river has cut its way. The ultimate results of this boring will be reported, but it does not seem necessary to delay this report for it.

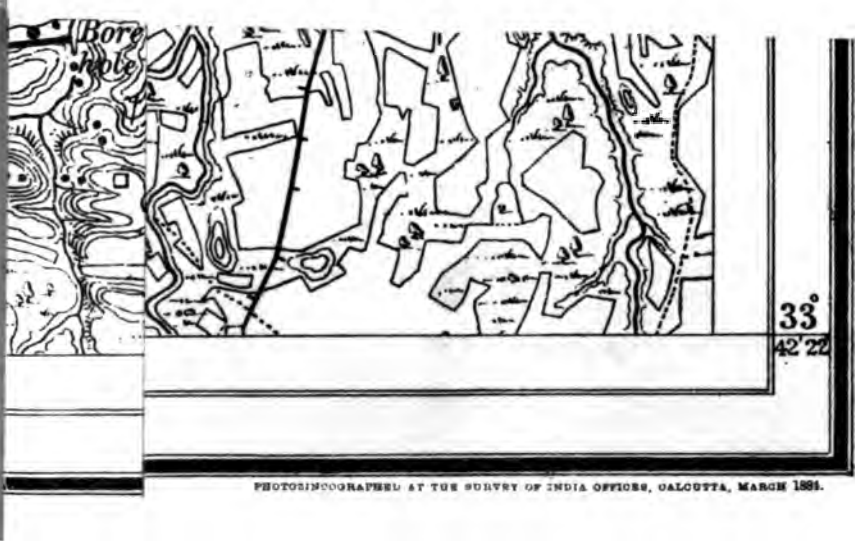
In conclusion, I beg to say that Mr. Scott has taken much pains with the work on which he was employed, and I trust that he will be more successful in the Salt-range, where I understand the manager of the line is about to employ him. He has been given the usual month's notice that his services will not be required further at Choi, and the tools, &c., used by him will be stored at Pindi until required elsewhere.

From J. T. O'CALLAGHAN, Esq., *Engineer-in-Chief, Northern Section, Punjab Northern State Railway, to the Director General of Railways,—No. 1851, dated 12th June 1883.*

In continuation of my No. 1335, dated 17th May 1883, I have now the honour to forward Mr. G. Scott's supplementary report on the bore-hole put down near the Haro river at the point marked F on the plan already forwarded.

I omitted to mention that the bore-hole was put down in the bed of the river about 70 feet below the average surface of the ground, and therefore represents a hole of a depth of about 320 feet.

The record shows that nothing but alluvial deposits have been passed through, and go further to confirm the views I have always expressed regarding this district.



PHOTOZINCOGRAPHED AT THE SURVEY OF INDIA OFFICES, CALCUTTA, MARCH 1884.

BORI

Supplement to report on the Choi Coal Exploration.

In this supplement, I purpose to give a further account of the deep boring near the River Haro, mentioned in No. 5 paragraph of my former report. On referring to that, it will be seen that the boring had nearly reached the depth of 200 feet, and my supposition was that a bed of limestone was close at hand. It was then thought that it would be advisable to discontinue the work, but after further discussion it was decided to go on, and see what the nature of the stone was.

Accordingly, after clearing the boring, it was re-started on the 19th May, and at the depth of 201′ 6″ sandstone was reached; the rock proved, however, to be only 4″ thick, and below, beds of loam, sand, and dark yellow clay were met. At a depth of 233′ 11″ sandstone with a total thickness of 8′ 3″ was bored through, and then again a bed composed of a mixture of loam and sand was found.

Finally, on the 7th June the boring was abandoned, the depth then reached being 252′ 6″ and the strata sandstone.

From the above short account, and from a study of the boring sheet noting the various strata pierced, the conclusion arrived at is, that even at the depth of 250 feet the boring had not gone below the silt and sediment deposited by the river: how far this deposit extends is a matter of conjecture, but, in my opinion, it would be some time before it could be bored through, and then no advantage would accrue, as it is highly probable limestone would be the strata met with.

The boring itself was put down in a ravine close to the Haro, and only 8 feet above low-water level. The cliffs which border one side of the river are 70 feet high, so that it will be seen that at the termination the boring was really 320 feet below the actual surface.

To have continued would have been a mere waste of time and money, as I have not the slightest hesitation in saying that a further search would prove utterly useless.

In my opinion, everything has been done with a view of finding a profitable seam of coal; the borings and trial pits have been put down in the most advantageous places, but without the success I confidently expected from the surface indications.

Section of Boring on the Haro River.

Depths.	Strata.	Depths.	Strata.
21′ 0″	Soil and pebbles.	194′ 5″	Loam and sand.
37′ 0″	Yellow clay.	201′ 6″	4″ sandstone.
70′ 0″	2′0″ sandstone.	204′ 9″	Loam and sandstone.
83′ 6″	Yellow clay.	211′ 2″	Loam and sand.
94′ 10″	2′ 6″ sandstone.	217′ 5″	Dark yellow clay.
108′ 0″	Yellow clay.	233′ 11″	Soft sandstone.
115′ 0″	Running sand.	242′ 0″	Loam and sand.
121′ 4″	Yellow clay.	249′ 3″	Sandstone.
144′ 2″	Blue clay.	252′ 6″	...
184′ 9″	Dark blue clay.		

NOTE.—If Mr. Scott's figures can be trusted, of which I regret to hear there is some doubt, the boring on the Haro would be of considerable geological interest, as proving that this great spread of alluvium, the principal area of which is known as the Peshawar valley, lies in a deep rock

basin. It has indeed become a safe general inference, that areas of deposition are thereby areas of depression; still new facts in evidence are not superfluous. The surface level at the boring is only about 25 feet above that of the Indus, twelve miles to the west, where it turns at a right angle into its gorge through the Chita range.

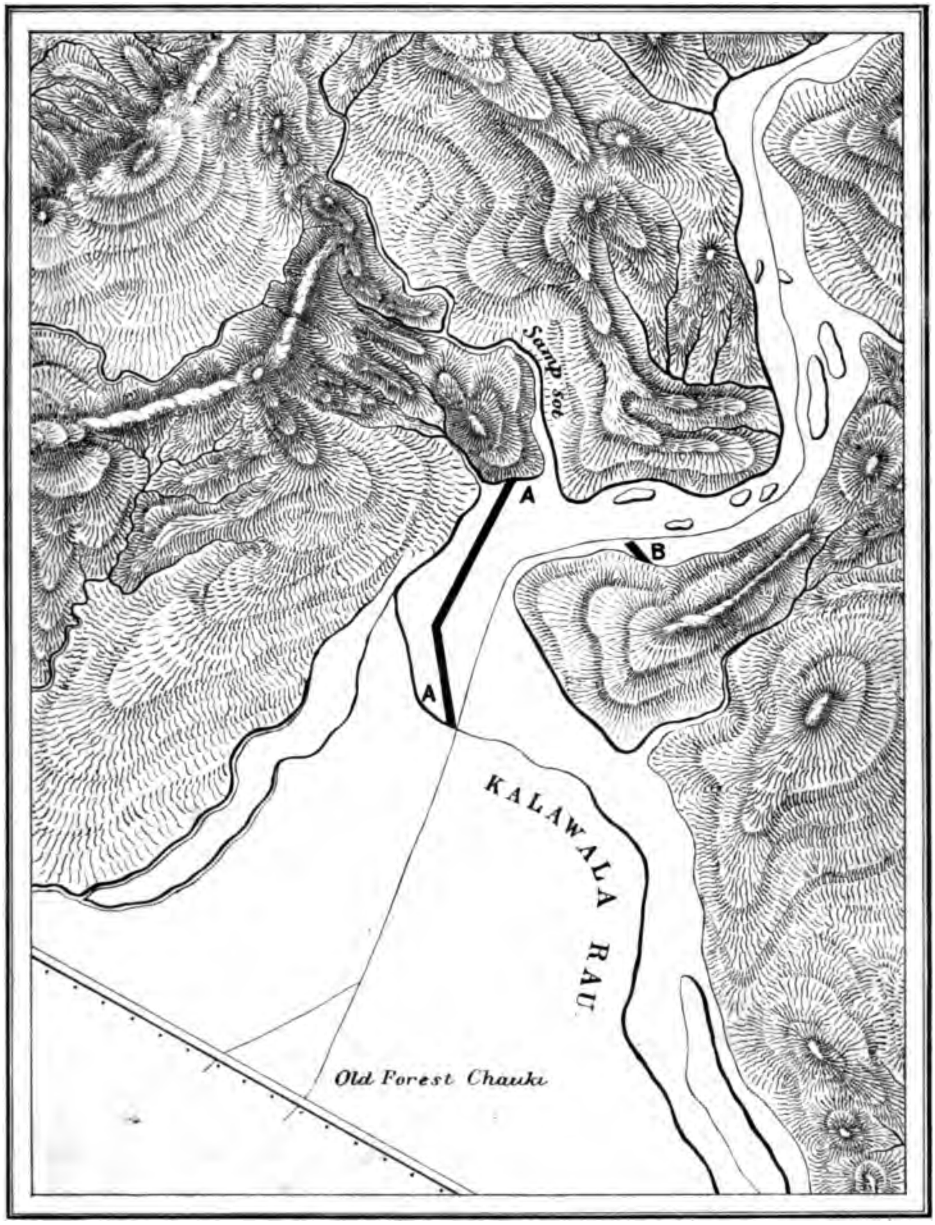
The expectation to find the coal flat and abundant under the alluvium in a region of extreme contortion as exhibited in the surrounding hills, is a speculation that could only occur to the "practical man."—H. B. M.

On the re-discovery of certain localities *for* fossils *in the* Siwalik *beds, by* R. D. OLDHAM, A.R.S.M., *Geological Survey of India.* (With a map.)

Having recently had the good fortune to re-discover the long-lost fossil locality described by Sir Proby Cautley at the base of the section in the Siwalik hills, it has been considered desirable to put on record a detailed description of the locality.

For this discovery I am mainly indebted to Mr. A. Smythies, Deputy Conservator of Forests, who, when deputed a short while ago to enquire into the question of the effect which the clearing of the forests from the slopes of the Siwaliks has had on the floods that annually enter and cross the Eastern Jumna Canal, made careful enquiries of the survivors of those who were employed on its construction as to the locality from which the fossils had been obtained; the result of his enquiries was that they had been discovered during the excavations carried on in connection with the works in the Kalawala Rao. These, which are shown in the annexed sketch plan, consist of the principal bund, A, which was designed to throw the waters of the stream into a channel which does not enter the canal, and a small spur, B, higher up stream, intended to guide the current against the principal dam. On visiting the spot we found at the head of both the principal dam and the spur a very peculiar rock, a conglomerate with a calcareous sandy matrix full of fragments of clay and decomposed slate with hardly a particle of harder rock; such might very properly be called a "clay conglomerate," but "clay marl" must be acknowledged to be a misleading name; still gravelly clays are sometimes improperly called marls, and the name might be applied by an engineer who did not profess to be a geologist. Through this rock are scattered, though not abundantly, small fragments of bone, always broken, water-worn, and disjointed, and without exception converted into oxide of iron (hæmatite). As described by Sir Proby Cautley, reptilian teeth were not uncommon; besides these we found a mammalian molar imbedded in a portion of the ramus, a piece of the thigh bone of a small animal about the size of a sheep, a piece of a rib of some large animal, and portion of the carapace of a tortoise.

As regards its position in the section, the bed is exposed in the Kalawala Rao on the southern side of the anticlinal fully 1,000 feet above the lowest beds seen; here there are two distinct beds, but in the valleys to the west three or more are occasionally seen. The same or similar beds are well seen in the Kotri and Kusumri Raos, but I was unable to detect them in the Badshai Rao (Timli pass), while to the eastwards I doubt not it would be found if searched for, as I have seen a very similar bed in the Dholkund Rao, but at the time expecting to find the fossils in a clay bed I did not search it.



On Stone by S. K. Hossain

SOUTH ENTRANCE OF THE KALAWALA PASS, SIWALIK HILLS.

Scale 4. = 1. Mile

This has an important bearing on the discovery of similar fossils on the northern face of the Nahan hill;[1] it is of course possible that the lower beds of the Siwalik range are of the same age as those of which the Nahan hill is formed, but taking into consideration their very different mineralogical facies and the fact that they being situated at a greater distance from the Himalayas are far more exclusively composed of sand and pass up into coarse conglomerates, it can hardly be called probable, and it is far more likely that the Nahan fossils were either of an entirely different age or that they were obtained from an outlier of the middle Siwaliks, as has been suggested by Mr. Medlicott (Mem. Geol. Surv. India, III, 105), and again by Mr. Theobald (Rec. Geol. Surv. India, XIV, 71).

On some of the Mineral Resources *of the* Andaman Islands *in the neighbourhood of* Port Blair, *by* F. R. MALLET, *Deputy Superintendent, Geological Survey of India.*

Towards the end of last year specimens of various minerals, which had been discovered in the neighbourhood of Port Blair by Mr. M. V. Portman, Assistant Superintendent, were sent to the Geological Survey Office for examination. Amongst them were found ores of chromium, copper, iron, and sulphur. Later on Mr. Portman himself visited Calcutta, bringing with him further samples. Judging from these, and from the account given by Mr. Portman of the ores as found *in situ*, the indications seemed to be sufficiently promising to make an examination of the ground advisable. I was accordingly directed to proceed to Port Blair and carry out such investigation.

Geological character of the country near Port Blair.

Although it may be assumed with some degree of probability that the geological structure of the Andamans is of very much the same character throughout, the only portion of the islands concerning which we possess any certain knowledge, from direct observation, is that comparatively near Port Blair. Messrs. Kurz[2] and Ball[3] have shown that the strata are mainly sandstone and shale, which have been much altered in places through the intrusion of eruptive rocks.

From Mount Harriet, one of the culminating points of a ridge to the north of the station, and about 1,200 feet above the sea, a wide bird's-eye view can be obtained, which gives a good general idea of the orography, and indeed of the geology too, of the surrounding country. The island for many miles to the north of the harbour and Port Mouat is traversed by a number of parallel ridges, running a little east of north, which, like the Mount Harriet ridge itself, are probably formed, in the main, of sandstone and shale, with rather a high dip in most places. The sandstone is generally fine-grained, of yellowish-white, grey, or greenish tints. Nests of lignite have been found in it here and there. Occasionally it includes subordinate layers of conglomerate, composed of small, well-rolled, mostly quartzose pebbles. More or less calcareous beds are also found

[1] *Vide* Mem. Geol. Surv. India, III, pp. 15-16. Rec. Geol. Surv. India, XIV, 71, note.
[2] Report on the vegetation of the Andaman Islands, p. 2.
[3] J. A. S. B., 1870, Vol. XXXIX, Pt. 2, p. 231.

amongst the sandstones, but I am only aware of one band of pure limestone.[1] Between some of the ridges, at least, there are level bottoms of alluvial land. Although this part of the island would seem to be composed very largely of sedimentary strata, eruptive rocks are by no means absent, serpentine, &c., having been met with in several places. The structure of the hills to the south of the harbour appears to be less regular, and this irregularity would seem to be due to the greater development of eruptive rocks there. Of these the most important is serpentine, which occurs both in large masses and in dykes. The north-east part of Rutland island is mainly formed of it, the rock being dark green and often spangled with small crystals of bronzite. Seams of white (triclinic?) felspar, a few inches thick, traverse it here and there, but are not common. There are also occasional thin seams of cellular quartz, containing some earthy oxide of iron, or of manganese, in the cavities. Small layers of brown opal have been met with in the same connection. These seams occur between joints in the serpentine: the jointing is often strongly marked, and, when highly developed in one direction only, gives the rock somewhat the appearance of bedding. Serpentine is also largely developed at Bird's Nest Cape and to the north, at Homfray's Ghát, and other places. Hornblendic, chloritic, and felspathic forms of rock are frequently found in association with it.

On referring to the map of India one sees that the line of elevation constituting the Arakán Yoma is represented further south by the Alguada reef, Preparis and Coco islands, and the Andamans. The orographical connection between the Arakán and Andaman ranges is accompanied by an equally close geological one. The formations of the latter "are extremely similar in appearance to the Negrais rocks of the Arakán Yoma, and in all probability belong to the same group."[2] Serpentinous intrusions are also common in the rocks of both localities.

In as far as any *a priori* opinion can be formed from the above geological connection as to the metallic wealth of the Andamans, such opinion must be of an unfavourable character, as no useful ores are known to occur in the Arakán Yoma. "The only ores [in Burma] which need be noticed for practical purposes," says Mr. Theobald, "are those of iron, tin, lead, copper, antimony, none of which, save iron, are known west of the Sittoung,"[3] and the localities noticed by the same writer, where iron has been worked, are to the east of the Irrawádi. The apparent barrenness of the Arakán hills, however, cannot be taken as conclusively proving that the Andamans are equally unproductive, although certainly tending to suggest that such may be the case.

Hematite, pyrite, and chalcopyrite at Ráng-u-Cháng.

Along the sea coast at Ráng-u-Cháng, a place some miles south of Port Blair, are highly altered or eruptive rocks. Here and there these are traversed by veins, the main constituent of which is hematite, but which include a considerable proportion of pyrite (iron pyrites) and chalcopyrite (copper pyrites) in much smaller quantity. The veins constituted of these ores are very irregular and sometimes

[1] P. 85.
[2] Manual of the Geology of India, Pt. 2, p. 733.
[3] *Supra*, Vol. VI, p. 91.

branching, but short and strangulated, none that I saw being traceable for more than a few yards. In one place I observed a mass of pure pyrite more than a foot thick and two feet long, but it could be seen that vein died out completely within a few feet. Although, therefore, individual specimens of somewhat imposing dimensions can be obtained, I saw nothing leading me to suppose that the mineral could be profitably worked. Nothing like a steady vein is to be seen, and it would be obviously hopeless to mine on the chance of meeting with scattered irregular nest-like veins like the above. The same remarks apply to the copper pyrites. The proportion is too small, and the cupriferous veins too irregular, to allow of profitable work, although an occasional lump of some size may be obtained.

In the jungle, perhaps 50 yards from the beach and the above-mentioned veins, Mr. Portman had excavated some tons of ore, from what seems to be a true lode running in a N.—S. direction. At the main excavation the lode is several feet thick at least, but the entire breadth was not exposed at the time of my visit. The ore, taken in bulk, is composed mainly of chloritic quartz and hematite (occurring chiefly as micaceous iron). The other constituents are iron- and copper-pyrites. Although large lumps of good hematite can be obtained (one that I saw contained a couple of cubic feet of mineral free from admixture), the ore in bulk is worthless as an ore of iron, firstly on account of the large proportion of quartz, and secondly on account of the pyrites, which is still more fatal. The quartz might be separated to a considerable extent by picking, but it would be impossible to free the ore from sulphur in this way. To mine in hard rock, and then hand-pick such a sulphurous ore, would be manifestly impracticable, when high-class ore in inexhaustible quantity is to be had on the surface in so many parts of India. The amount of iron pyrites is too small to allow of the ore being worked for sulphur, and the proportion of copper pyrites is quite insignificant, although here and there a lump of some size may be obtained, one piece that I secured containing a couple of pounds of solid ore.

The above is the opinion that I formed on the spot, but I have, since my return to Calcutta, been able to check it by assays of the ore. A quantity, weighing perhaps a couple of tons, and which may be taken as a fair sample of the whole, had been brought in to Port Blair, and at my request Mr. Portman had about three-quarters of the amount broken up small. The broken ore and dust were thoroughly mixed together, and a large bagful taken, which was reduced to powder in the laboratory here and mixed again. On assay it yielded—

	Per cent.		Per cent.
Copper	·10	= Copper-pyrites	·30
Sulphur	10·74	= Iron-pyrites[1]	20·13
Insoluble siliceous residue	37·60		

More than half a million tons of pyrites are now used per annum in England for the manufacture of sulphuric acid. The average percentages of sulphur in the mineral imported from different countries are as follows:—

	Per cent.
Spanish and Portuguese	46 to 50
Westphalian	44·5

[1] After deducting the sulphur in the copper-pyrites.

	Per cent.
Belgian	44
Swedish	42
Italian	35 to 46
Irish	35
Cornish	28

Out of 550,000 tons imported about 1880, 500,000 were from Spain and Portugal.[1] Cornish and Irish pyrites "are, as a rule, cupreous ores, but of very low value. Their chief fault is the poor percentage of sulphur, whereby the cost of carriage and manipulation, &c., is, of course, very largely increased. All payments for storing, carrying, breaking, burning the ore, and treatment of the burnt residue, are as large for weak as for rich qualities, and therefore far heavier, relatively."[2] With reference to the value of these ores, 65,916 tons were raised in the United Kingdom in 1872, valued at £39,470, or £0-11-11$\frac{3}{4}$ a ton: in 1882, 11,074 tons were raised in Ireland, valued at £5,743, or £0-10-4$\frac{1}{2}$ a ton. It will be seen, then, that the poorest class of ore in the English market contains about three times as much sulphur as that of Ráng-u-Chńg, and although the ore derives its value in part from the small amount of copper it contains, which is extracted from the residue after the pyrites is burnt, still it only fetches 10 or 12 shillings a ton. The Ráng-u-Cháng ore would be unsaleable at any price, as the proportion of sulphur is so low that the ore would not support combustion in the kilns. The pyrites could not be concentrated by hand-picking, firstly, because it is too much scattered through the gangue; and secondly, because, being much more brittle than the quartz and hematite with which it is associated, it would be broken during the operation into a powder which would require subsequent washing for its separation. Such 'smalls' do not fetch more than a third the price of pyrites in lumps. At present there is no demand for pyrites in India, but were such to spring up, ore like that hitherto obtained in the Andamans could not possibly contend against that from Spain.

It is well known that many pyritous lodes contain little or no good ore at the surface, but at a moderate depth are rich enough. This, however, is due to the decomposition of the back of the lode, and the carrying down of the valuable constituents in solution as sulphates. The Ráng-u-Cháng ore is perfectly fresh and unchanged close to the surface, and consequently there is no such reason to anticipate an improvement by sinking deeper. The lode may improve below the surface, but there are no grounds for anticipating that it will. The same may be said with reference to the longitudinal extension. By excavating along the course of the lode it may be found richer in some parts than where it has been tried, but it is quite as likely that it may be found very much the same,[3] or even poorer. I recommended that a cut should be made across the lode at the present excavation, so as to ascertain the entire width, but at the time labour could not be spared.

[1] A Manual of the Alkali Trade, by John Lomas, p. 13.

[2] *Ibid.*, p. 11.

[3] Mr. Portman had made a smaller excavation at some distance from the main one, and the ore was of the same character.

The ore was also assayed for gold, and found to contain a minute trace only, with no silver.

Pyritous vein at south Corbyn's cove.

A little south of Corbyn's cove the road to Brookesabád crosses a vein, which, on the west side of the road, is five yards thick. The rock is a ferruginous and chloritic quartz containing a little iron pyrites disseminated through it, and copper pyrites in still smaller amount. Between the road and the sea the vein is less definitely marked, being represented by several irregular smaller veins. One of these consists of quartz containing a fair proportion of copper pyrites[1] mixed with iron pyrites. As the vein is two feet thick at one point, large blocks of ore can be obtained presenting rather an attractive appearance, but within a few feet the vein thins out to two or three inches, then thickens somewhat again, and a few feet further on dies out altogether. Taking the main vein in bulk, the proportion of copper ore is very low, while as a source of sulphur the amount of pyrites is quite insignificant. The pyritous quartz was assayed for gold (and silver) and found to contain none.

The vein runs about S. 20° W., and may possibly be a continuation of that at Ráng-u-Cháng. If so, there is a considerable change in the character of the ore, that at Corbyn containing much less iron and more copper.

Clay-ironstone nodules in shale.

Some of the shales in and about Port Blair contain lenticular nodules of clay-ironstone of varying size up to 6 or 8 inches diameter. They are not sufficiently plentiful, however, to be of any practical use.

Magnetic iron sand.

A specimen of black iron-sand from Havelock Island, which was sent to me by Colonel Cadell, the Chief Commissioner, was found to consist of magnetite.

Chromite at Chakargaon.

In Volume XVI, p. 204, an extract is given from an official letter of Mr. Portman's to the Chief Commissioner, describing the position in which a large block of chromite, and some smaller pieces, were found at the village of Chakargaon. Mr. Portman pointed out the locality to me, of which I subsequently made a close examination. The village is situated at the foot of an irregular line of rounded hill which runs south-westwards from Mount Haughton, and which is formed of sandstone and shale with some subordinate calcareous strata. The large block of chromite was found a little south of the village by the side of a small watercourse. It was a loose piece resting on, and partly embedded in, a talus composed of sandstone fragments. The other lumps were found close by in a similar position. Just south of the block is a somewhat larger watercourse, in which an almost continuous section of the rocks is exposed from the foot of the hill to near the top. They are exclusively shale and sandstone, with a high dip to the south-east, and no fragments of serpentine (or of chromite) are to be found in the stream. The hill is, I believe, beyond doubt composed entirely of shale and sandstone from the position in which the chromite was found to the summit. As there is every reason to suppose that the chromite here, as in so many other parts of the world, occurs in connection with serpentine, it is, I think, certain that

[1] About 30 per cent., or 10 per cent. of copper.

the blocks did not come from the hill-side above. From the site of the block there is a gentle slope downwards for about 20 yards, at the foot of which an alluvial flat begins, beneath which there may be a mass of chromiferous serpentine which formerly extended over the position of the block, but which has been cut away by denudation. At the very foot of the hill, indeed, there is a mass, some feet across, of a serpentinous rock mixed with calcite.[1] Similar rock can be traced at intervals along the foot of the hill, both to the south-west and the north-east, but although I followed it for about a mile, not a single piece of chromite was to be seen in connection with it.[2] I had a trench excavated across the outcrop of this rock at Chakargaon, but no chromite had been met with at the time I left Port Blair. I think the continuation of this trench would be the best way to carry on the work, although I cannot say that I feel very sanguine of success. That there is a deposit of chromite concealed somewhere not far from the spot where the blocks were found, is clear, but that such deposit is a large or persistent one is more doubtful. If a strong vein, or number of lenticular masses extending along a certain line, existed of such ore, which is not liable to decomposition, the mineral would most probably betray itself by fragments along the outcrop. Yet none such have been found except in the one spot.

Chromite at Rutland Island.

The occurrence of the mineral at Chakargaon being an indication that the Andamanese serpentine is more or less chromiferous, it seemed to me that the localities where serpentine was known to occur elsewhere should be examined. With this view I went with Mr. Portman in the G. S. *Celerity* to Rutland Island, the north-eastern part of which is almost wholly composed of the rock in question.[3] I ascended four different streams, but in none of them was a single pebble of chromite to be found. Mr. Dawson, however, in washing for platinum in three of these streams,[4] obtained more or less fine black sand, which on examination proved to be the mineral we were in search of. On the sea beach, at the mouth of one of the streams, similar sand, which had been brought down by the current and then beaten back by the waves, was met with in layers more than an inch thick. When the sand from all these localities is examined under the microscope, it is seen that, in considerable proportion, the grains are well-formed octahedral crystals, with the edges scarcely at all rounded by attrition. By pounding, sifting, and elutriating the massive chromite of Chakargaon, a sand can be artificially produced which, to the naked eye, resembles that of Rutland Island, except that it is less lustrous in appearance. Under the microscope, however, no crystals can be detected, the sand being made up of irregular broken fragments. It is the crystalline facets of the Rutland Island sand which gives it its lustre.

Taking, then, into account that not a single fragment of massive chromite was found, and that the sand could not, apparently, have been produced from the comminution of such, I am strongly inclined to believe that the mineral occurs

[1] The "diorite and porphyritic trap," mentioned at p. 204, Vol. XVI, do not exist.

[2] The hill has been completely cleared of jungle, so that the outcrop is not concealed by vegetation.

[3] P. 80.

[4] P. 85.

disseminated through the serpentine in minute crystals, and therefore in a form of no practical value. I should mention that one of the streams ascended was not more than half a mile long altogether, the place where the sand was obtained being about midway in its course. Even, then, putting the crystalline character of the sand out of count, it is difficult to believe that the substance in mass could be so completely and finely comminuted during so short a journey.

Search for chromite elsewhere.

I also examined the serpentine at Bird's Nest Cape, at Homfray's Ghát, in the hills south of Corbyn and Protheroepur, and in more than one locality north of the harbour, but found no massive chromite at any of those localities. I cannot help suspecting, therefore, that the mineral is not very plentiful in that part of the Andamans. The contrast between the streams in Rutland Island and those in the Hánlé Valley in Ladák,[1] where also serpentine is largely developed, is very marked. In the latter, lumps of chromite, often many pounds in weight, are scattered about in plenty.

Search for platinum.

In the not very numerous cases in which platinum has been traced to its parent rock in other parts of the world, it appears to have been found, in most instances, either in auriferous quartz veins traversing crystalline rocks, or (accompanied frequently by chromite) in serpentine. Search was consequently made for it at Rutland Island. Mr. Dawson, the gunner of the *Celerity*, who had had many years' experience in Australian gold-washing, washed in three different streams, but not a single particle of the metal was found.

Limestone.

About 300 yards north-east of Chota Protheroepur a band of massive cream-coloured and greenish-white limestone, containing veins of calcspar, outcrops at the foot of the hill. The strata dip at a high angle, and the band is several yards thick, but does not show above the alluvium for more than 30 yards or so along the strike. The same band outcrops again, however, with a thickness of 10 or 12 yards, in a hillock about half a mile N. 35° E. of the village. Although it is only exposed at the south-west end of the hillock, it probably extends the whole length, for say 100 yards, beneath the surface soil; if so, there is a large supply above the level of the alluvium, and consequently available by open quarry. On the north-west side of the village of South Corbyn the rock outcrops a third time, forming a small hillock. The band seems to be about 8 or 10 yards thick, dipping at 70°: part of the limestone there is reddish.

An analysis of the rock from the first-named outcrop gave—

Carbonate of lime	96·45
" " magnesia (by diff.)	·09
" " iron	1·16
Insoluble residue (mostly sand)	2·30
	100·00

As there appears to be a considerable (although not unlimited) supply available from free-draining quarries, and a much larger quantity by going beneath

[1] Memoirs, G. S. I., Vol. V, p. 166.

the level of the alluvium, it is worth consideration whether this limestone could not be profitably exported to Calcutta.[1] The most distant outcrop is less than a mile from the sea at Corbyn, where the stone could be loaded into boats and taken round to the harbour. Lime has for some years past been imported into Calcutta from Katni, in the Jabalpur district; if it pays to transport it more than seven hundred miles by railway, it would certainly seem that it ought to pay to transport the stone about the same distance by the much cheaper sea carriage.[2] The Andaman stone is fully equal in purity to the best of that from Katni, an analysis of the latter yielding—

Carbonate of lime	94·65
„ „ magnesia (by diff.)	2·98
„ „ iron	·58
Insoluble residue	1·79
	100·00[3]

Besides its use for lime, the Andaman stone would make a good cream-coloured marble. It could be quarried in large blocks, or in slabs, several feet in length and breadth. A reddish marble could also be obtained.

While on the subject of lime, I may mention that there is an inexhaustible supply of volcanic ash, or puzzolana, at Barren Island, similar to that obtained from some of the extinct volcanoes of Central France, and so largely used there as an ingredient of hydraulic mortar.

Serpentine.

Mr. Ball has already alluded to the serpentine at Homfray's Ghát, from an economic point of view.[4] The stone is mostly weathered and shattery on the surface, and to obtain it in a perfectly sound condition it would be necessary to quarry some distance into the hill-side. Scattered over the hill, however, especially near the top, are numerous large blocks of stone which have resisted disintegration to a great extent, and some of which are fairly sound, although, being more or less fissured, it is doubtful if slabs of large size could be cut from them. But if serpentine should be locally required in small quantity, for the supply of which it would not pay to open a regular quarry, these blocks would be worth attention.

Serpentine is known to exist in many other places, but, taking quality into account, there is none, perhaps, more favourably situated than that just mentioned.

Jasper.

In the midst of some reclaimed land at Aberdeen Mr. Portman discovered a large mass of variegated red jasper, which has doubtless been exposed through the denudation of the softer rocks around it. It would make a handsome ornamental stone if polished, but in cutting large slabs there would be some risk of meeting with drusy cavities which occur here and there through the rock.

[1] The lime now used at Port Blair is made from coral, but I was informed by Colonel Protheroe, the Deputy Superintendent, that it is of rather inferior quality, as the salt cannot be thoroughly washed out of the raw material, and subsequently effloresces out of the mortar.

[2] In this connection it may be noted that 100 maunds of (pure) limestone yields 56 maunds of quicklime and 73 of slaked lime.

[3] Vol. XVI, p. 112.

[4] J. A. S. B., 1870, Vol. XXXIX, Pt. 2, p. 237.

The Intertrappean beds *in the* Deccan *and the* Laramie group *in* Western North America, *by* M. NEUMAYR. (*Translated from the Neues Jahrbuch für Mineralogie, etc., 1884, Vol. I.*)

White's recent work on the fossil land and fresh-water shells of North America [1] gives for the first time a good account of these forms, the literature concerning which was formerly so scattered as only to be studied with much trouble; many relations are shown to extra American forms, amongst which I propose to consider at least one, since the subject not only possesses interest itself, but also serves the purpose of correcting a former erroneous opinion of mine.

Many years ago Hislop [2] described several shells occurring in some fresh-water beds at Nagpur interstratified with the enormous basalt masses of the Indian peninsular, known as the Deccan trap. The most generally received opinion is that these beds belong to a period on the boundary between the cretaceous and tertiary epochs; since, however, a *Unio* resembling our European *U. flabellatus* was found, and the genus *Acella*, which at that time was only known in the pliocene of Slavonia and living in North America, is represented, I ventured to point out the possibility that the intertrappean beds might belong to the later tertiaries. [3] A comparison between the fossils of these intertrappean beds and those of the Laramie beds of North America which lie between the chalk and eocene shows very close relations between the two, and I can no longer hold my former opinion in the face of these results.

Though the number of the genera of the fresh-water shells of Nagpur is far from small, the greater part is so indifferent, or the preservation and description so insufficient, as to render only the smaller half of use for judging of the character of the fauna; amongst these the most important is *Physa prinsepi*, Sow., which reminds one of the large kinds of Physa of the Paris and London eocene, but which is also closely related to the Laramie fossils of America, as *Ph. copei*, Wh., and *Ph. disjuncta*, Wh. The above-mentioned exceedingly attenuated *Limneæ* which have been grouped together in the subgenus *Acella*, and which are represented in the Laramie beds by *A. haldemani*, Wh., form another striking occurrence; *Paludina virapai*, Hisl., closely resembles *Hydrobia anthonyi*, M. and H. Among the snails a few other similar cases occur, the forms, however (*Paludina acicularis—Hydrobia recta, Paludina conoidea—Hydrobia subconica*), are so little distinctive that I place small value on them. The Valvata are the only characteristic gasteropod types of Nagpur not represented in the Laramie beds of North America.

Among the mussels the Unios are foremost; they have much in common in general appearance, but *U. carteri*, Hisl., a form of the type of the European *U. flabellatus*, is the only one that shows any close connection with *U. gonionotus*, Wh., and *U. gonioumbonatus*, Wh., of North America. Finally, *Corbicula ingens*, Hisl., is remarkably similar to *Corbicula cleburni*, White.

[1] White, a review of non-marine fossil mollusca of N. America. Extract from the annual report of the Director of the U. S. Geological Survey, 1881-82.

[2] On the tertiary deposits associated with trap-rock in the East Indies. Quart. Journ. Geol. Soc., 1860, page 154.

[3] Neumayr und Paul, Congerien- und Paludinen-schichten Westslavoniens. Abhandlungen der geolog. Reichsanstalt, Vol. VII, 1875.

Whether in the one or the other case there may be actual identity, or whether it is, as I think more probable, a case of near related vicarious species, I cannot decide. On the whole the following forms may be correlated:—

Nagpur.	Laramie.
Physa prinsepi	*Ph. copei.*
" " var. *elongata*	*Ph. disjuncta.*
Acella attenuata	*Ac. haldemani.*
Paludina virapai	*Hydrobia anthonyi.*
Unio carteri	{ *Unio gonionotus.* " *gonioumbonatus.*
Corbicula ingens	*Corb. cleburni.*

These facts justify the conclusion that the intertrappean beds of India are the most nearly related of any fresh-water beds yet known to the Laramie beds of North America—a result which agrees well with the most generally received opinions with regard to the age of both. Whether both belong to cretaceous or tertiary formations the fresh-water shells give no decided means of judging; many forms—for example, the large *Physa*, *Melania wyomingensis*, and others of the Laramie beds—are nearly related to tertiary types, but side by side with this are found surprising relations to European cretaceous forms. I will not, however, enter here more particularly upon this point, since Dr. Tausch is at present engaged in my institute upon studies which will yield evidence in this direction.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1884. [August.

On the microscopic structure *of some* Arváli rocks, *by* COLONEL C. A. MCMAHON, F.G.S. (With a plate.)

Dosi.

Dosi, an isolated hill within the Arváli area,[1] between Narnoul and Khetri, rises more than 1,000 feet above the neighbouring plain,[2] and forms a striking object for many miles around. Its steep sloping sides and cup-like top give the hill an appearance not altogether unlike a volcano.

It is curious how prone some people are to think that every cup-like depression observed on the crest or spur of a mountain is an old crater. I have several times been asked whether Kajiár, a beautiful glade in the forest within 9 miles of Dalhousie, is not an old volcano, although there is not a modern volcanic rock in the whole district, and the upper silurian, or pre-carboniferous, altered basalts are many miles distant.

In the case of Kajiár and Dosi, the formation of these cup-like depressions seems to be in great part due to what one may call the eccentricities of sub-aërial decay. Crystalline rocks, apparently composed of exactly the same materials, and struck out of the same mould, as it were, vary very capriciously within a few yards in their power of resisting the elements of decay.

Many curious instances of this are to be seen at Dosi, where deep grooves, several feet in depth and in diameter, have been carved out of the sides and faces of huge granitic blocks by sand-laden wind aided by the selective agency of natural decay. When they are of small size, they remind one very much of the pot-holes and furrows, formed by the action of water, so often to be seen carved on boulders in the beds of Himalayan rivers; but such agency is of course not to be thought of in the case of rocks on the top of an isolated hill, like Dosi, situated in a sub-desert tract, where the rainfall is very small. Moreover, in some of those carved horizontally out of the face of a rock the deepest portion is at times connected with the top and not with the bottom of the groove.

[1] Described by Mr. C. A. Hacket in his paper *On the Geology of the Arváli region, Central and Eastern*, Records XIV, 279.

[2] The point I reached, which was not, I think, the highest, was 2,110 feet above the sea by my Aneroid barometer and 1,110 feet above the village at its foot where the ascent commenced.

Nor is it necessary to call in the agency of water to explain the formation of these grooves. In the Dosi region, fierce westerly winds, heavily laden with sand from the neighbouring plains, prevail for many months during the year. Gullies amongst the rocks bring heavy gusts of wind to a focus, as it were, and make them do the work of sand-blast boring machines.

In the neighbourhood of Dosi and Narnoul, the hills, some of them consisting largely of actinolite schists, are traversed in all directions, but generally more or less across the strike of the strata, by dykes of white granite. It is a very coarse-grained rock consisting principally of felspar and quartz with occasional lumps of schorl 2 or 3 inches in diameter. Mica (white muscovite) is rather rare, but here and there it is well developed. Some of the quartz grains are larger than oranges, and I measured one 7 inches across.

Dosi itself is composed wholly of the rock, about to be described, which is marked gneiss on the map which accompanies Mr. Hacket's paper on the geology of the Arvâli region. It is a fine-grained rock of pale pinkish buff colour composed of quartz, felspar, black mica and black hornblende, the latter predominating over the mica.

A general parallelism in the arrangement of the hornblende and mica, and which coincides with the strike of the sedimentary strata in the neighbourhood, is observable in the field on a careful inspection. Sometimes the rock weathers out into smooth massive blocks, like true granite, at others it becomes slightly furrowed on the surface, the furrows striking north-east 15° east.

M.—Nos. 1, 2, 3, and 4. The following is a description of the structure of the Dosi rock as seen in thin slices under the microscope. These slices contain quartz, orthoclase, plagioclase, microcline, black mica, hornblende, micro-garnets, and a little magnetite.

The quartz is about as abundant as the felspar. Triclinic felspar is very plentiful, and there are numerous pieces of microcline, but none of them are of large size. Prismatic cleavage is frequently well exhibited in the orthoclase.

The quartz contains multitudes of liquid enclosures with fixed and movable bubbles, and in many, crystals have been deposited on the cooling of the liquid, as shown at figs. 23, 30, 31, 32, and 34. The enclosure depicted at fig. 23 contains a crystal and two bubbles. The right-hand one, which is a gas bubble, certainly moves, though the movement is confined to contracted limits; the left-hand one, which appears to be an ordinary vacuum bubble, is either fixed, or its vibrations are so circumscribed that I could not feel sure that it really moved.

Figs. 30, 31, 32, and 34 of the plate which accompanies this paper may be usefully compared with figs. 79, 80, 81, and 83, Plate XVIII, Q. J. G. S., Vol. XIV, which accompanies Dr. Sorby's paper on the microscopical structure of crystals, and which depict similar liquid cavities found in nepheline blocks ejected from Vesuvius.

The quartz of the Dosi rock contains numerous liquid cavities with gas bubbles. One of the latter type is sketched at fig. 33.

At fig. 35 I have depicted a liquid cavity contained within a negative quartz crystal; that is to say, the *cavity* has assumed the shape of a small quartz crystal with bi-pyramidal terminations. There is no doubt about its being a liquid

cavity as the bubble is a movable one. Cavities of this character seem to prove that the quartz was in a state of flux, as does also the presence of some perfectly hexagonal microlithic plates of mica enclosed in it here and there.

Fig. 35 of the plate attached to this paper may be compared with fig. 114 of Plate XIX of Dr. Sorby's paper just referred to. The latter represents a liquid cavity, in the shape of a quartz crystal, containing a bubble and a deposited crystal. The cavity was observed in the quartz of the granite from the Ding Dong mine near Penzance.

Some of the bubbles in the liquid cavities observed in the Dosi rock appear to be ordinary vacuum bubbles, but many of them are gas. The latter are quite round, but occupy a much larger area relative to the size of the cavity than the vacuum bubbles and affect light differently.

In one enclosure, which I have not sketched, the crystal deposited within it is distinctly cubical and is probably sodium chloride: those depicted in figs. 30 31, and 32 are corroded like the one represented at fig. 55, Plate XVII of Dr. Sorby's paper already quoted.

For the sake of comparison, I have studied some thin slices of typical rocks from Scotland prepared by Mr. J. M. Bryson, of 60, Princes Street, Edinburgh, from specimens selected for him by Professor Giekie. In them I find very similar objects to those described in the preceding pages. Fig. 24 is a liquid cavity containing a bubble and a crystal probably of sodium chloride, and fig. 25 represents a gas inclusion, both taken from granite invading metamorphosed lower silurian rocks.

In the Aberdeen granite, microliths, many of them apparently of quartz with bi-pyramidal terminations rounded or more or less modified, are very abundant in the quartz and felspar. They contain shrinkage cracks and cavities and lacunæ with fixed and movable bubbles. Figs. 26, 27, 28, and 29 are taken from the Aberdeen slice. Exactly similar bodies are common in the gneissose granites of the North-West Himalayas, and figs. 26—29 may be usefully compared with figs. 11 and 20 of the plate annexed to my paper in the last number.

Fig. 16 is the sketch of a stone enclosure found in the Dosi rock under description. It is a round mass of coloured crystalline matter enclosed in limpid colourless quartz. It contains four fixed bubbles of different sizes.

Such cases as those illustrated by figs. 16 and 35, taken in connection with the other illustrations, prove, I think conclusively, that the Dosi rock passed through a stage of aqueo-igneous fusion.

Under the microscope, no difference in structure can be detected between the Dosi rock and the intrusive granite of Aberdeen with which it has been compared, but nevertheless I hesitate to class the former as a true granite. The evidence shows at all events that either the Dosi rock is a true syenitic granite, or the metamorphism of a crystalline rock of the Dosi type is the result of aqueo-igneous agencies sufficiently powerful to flux the materials.

Delhi quartzites.

Nos. 5, 6, and 7 are from the rocky ridge to the north of Delhi, where our army took up its position during the memorable siege of 1857. These quartzites

range in colour from a light to a dark grey. With the aid of a pocket lens, very minute specks of dark mica, and of iron, may be discerned disseminated through them; and owing to the abundance of the iron, long tear drops may very frequently be observed coursing down the faces of weathered blocks. These rusty-looking streaks are formed by rain trickling down the sides of blocks and causing the peroxidation of the iron contained in the rock in the form of magnetite.

M.—These slices are seen under the microscope to contain numerous flakes of a colourless mica, minute garnets, prisms of schorl and micro sphenes. There are also rounded microliths of dark mica. Magnetite and much red and yellow ferrite are also present. Some of the garnets are much corroded at the edges, and altered into ferrite and into a greenish fibrous dichroic material.

The Delhi quartzite is an extremely interesting rock, as it contains evidence of having been subjected to great heat, sufficient to have allowed considerable freedom of motion amongst its constituent molecules. Microliths contain what are to all appearance shrinkage cavities, as for instance figs. 17, 18, and 21; very minute indeed, but still comparable with such illustrations taken from the Aberdeen granite as figs. 27 and 28. The evidence afforded by these microliths, however, is by no means conclusive, as in the case of a quartzite one might suppose that these bodies appertain to the quartz grains of the original sandstone, and that the latter were derived from some ancient granite and retained within them the stamp of their eruptive origin. But this cause of doubt is, I think, removed by the cumulative evidence afforded by the other objects about to be described, and by the fact that all trace of the quartz grains of the original sandstone from which the Delhi quartzite has been derived has been obliterated.

That the molecules of matter contained in the Delhi quartzite enjoyed considerable freedom of action is, I think, shown by such objects as those depicted at figs. 11, 12, 13, 17, 20, 21, and 22.

Figs. 12 and 17 illustrate the case of opacite drawn towards and attached to microliths, which in the former case had certainly formed before the opacite. Figs. 20 and 21 represent microliths, in the former case quartz and in the latter mica, which have caught up micro crystals and opacite, and have retained them in their embrace on consolidation. Similar bodies have also formed on the outside of the microlith depicted at fig. 20, and the latter also contains a fixed bubble. These objects very closely simulate the appearance of true stone cavities.

Fig. 13 represents an opaque crystal embraced by a flake of mica; fig. 22 is an air, or gas, bubble surrounded by a ring of coloured mineral matter; whilst fig. 11 is an air bubble partially clasped by minerals.

Fig. 19 is the representation of a liquid cavity of imperfect hexagonal shape, the imperfection of the shape being probably due to the fact that the slice was not taken at right angles to the axis of the cavity. I observed many liquid lacunæ of hexagonal shape in the quartz of slice No. 6, with movable bubbles in them, and their presence seems to show that the quartz prior to final consolidation was in a fused or plastic condition.

The cavity depicted at fig. 19 contains two liquids, and an inner bubble that is in a state of violent activity, dashing about from side to side in the wildest

possible way. The smaller drop of liquid is apparently carbon dioxide, as the movable bubble temporarily disappeared on the application of very low heat.

Ordinary fluid cavities with movable bubbles are extremely numerous throughout the quartzite.

Tushám.[1]

The village of Tushám is situated about 14 miles to the north-west of the town of Bhewáni, and about 85 miles west 11° north of Delhi.

The village nestles on the eastern side of a low rocky ridge under 2 miles in length, which, towards its centre, rises to a height of 630 feet above the adjoining plain and culminates in a conical hill that forms a striking land mark for 20 miles around.

The summit is difficult of access and is crowned by the ruins of a small fort, the building of which is popularly attributed to Raja Pithora.

Small caverns in the rocky side of the hill, partially filled with water, are considered peculiarly holy pools, and are visited by a number of pilgrims; three "melas," or religious fairs, being held during the year.

There are three rock inscriptions [2] at Tushám which, in General Cunningham's [3] opinion, belong to the time of the later Indo-Scythian Princes, and were cut between A.D. 57—69.

The eastern flank of Tushám is composed of chiastolite schists, the dip of which is either vertical, or extremely high west 11° north to west-north-west, and the strike of which ranges from north 5° east, on the north-east extremity, to north-north-east at the south-east end of the outcrop. To the west of these schists there follow pale grey argillaceous beds containing numerous small fragments of quartz, and traversed in all directions by red ferruginous lines.

The centre and western side of the ridge is composed of felsites, or micro-quartz porphyries, described further on. I was for some time doubtful whether these rocks were of igneous or of metamorphic origin, and thought they might represent beds similar to the argillaceous gritty rocks, alluded to in the last paragraph, in a more advanced stage of metamorphism; but now that I have examined thin slices of them under the microscope, I am satisfied that they are of igneous origin.

I may note in passing that whilst the specific gravity of the argillaceous rock referred to is as high as 2·95, that of the felsites ranges from 2·63 to 2·77 and averages 2·71.

Two dykes of quartz porphyry traverse the ridge, one on the eastern and the other on the north-western side. The latter cuts across the ridge from the north-west to the north-east side. The dykes are not parallel to each other, but their strike diverges at an angle of 46°. The eastern dyke cuts obliquely across the bedded rocks at a low angle; it throws out a tongue into the adjoining rocks, at

[1] Tushám and the neighbouring hills described in the following pages are coloured as gneiss on the map which accompanies Mr. Hacket's paper on the Arvâli region, Central and Eastern. Records, XIV, 279.

[2] One of these is said, in the Archæological Report, to be cut on basalt.

[3] Report, Archæological Survey of India, Vol. V, p. 136.

right angles to the direction of the dyke, and in another place, near the edge of the dyke, encloses a mass of them. The quartz porphyry is clearly an intrusive rock.

Granite crops out on the southern, south-western, and western flanks of the hill, whilst the northern portion of the ridge is traversed by granite veins ranging from a few inches to a few feet in thickness. Some of them cut across the strike of the other rocks. About a mile or so to the east of Tushám there is a small isolated hill of granitoid quartz porphyry.

I now pass on to describe briefly the characteristics of some of the Tushám specimens as seen in thin slices under the microscope.

Chiastolite schist.

No. 8.—Chiastolite schist from the south-east side of the Tushám ridge. A reddish-brown rock, with numerous minute plates of mica glistening on the surface, and in which radiating crystals of chiastolite are imbedded.

M.—The ground mass contains numerous shapeless grains of magnetite, and it is much stained with red and yellow ferrite. It is seen to be composed of quartz in grains, but the structure of the rock is very much obscured by the presence of a considerable quantity of iron. Most of it is in the form of hæmatite, rounded or imperfect hexagonal disks of the blood-red mineral being abundant.

The chiastolite crystals present nothing unusual in their appearance.

I failed to find gas or liquid cavities in the quartz.

Quartz porphyry.

Nos. 9-14. Sp. G. 2·67.—In a ground mass which appears compact to the unaided eye, numerous and rather large crystals of quartz and felspar are porphyritically imbedded. Some of the felspar crystals are an inch in length. With the aid of a lens, the ground mass appears to be a mottled mixture of felspar and dark mica. The pyramidal ends of some of the quartz crystals, nearly perfect in form, stand sharply out from the fractured surface of one of the hand specimens.

M.—The ground mass under the microscope is seen to vary in structure from micro-felsitic to micro-granitic. There appears to be a tendency in the material of the ground mass to arrange itself in concentric and radiating structures; nothing definite has resulted, however, from this tendency but shadowy phantoms that suggest rather than possess distinct forms.

There are two imperfectly shaped pieces of hornblende ranging from reddish-brown to greenish-brown colour in transmitted light. Dark mica is very abundant partly in congeries of small flakes and partly in stalk-like or quasi-prismatic forms. The latter look, at first sight, very much like microliths of hornblende, but they are of exactly the same colour as the mica, and I can discover no reason for distinguishing them from that mineral. They are so thin that between crossed nicols their optical properties are swamped in those of the matrix in which they are imbedded, and the usual tests for discriminating hornblende from dark mica cannot be applied.

Some of the mica is evidently of secondary origin and replaces other minerals the crystallographic outlines of which remain.

The slices contain some ilmenite. Gas cavities, and liquid lacunæ are very abundant in the quartz. At fig. 14 I have depicted a liquid cavity containing what is apparently a corroded crystal of sodium chloride together with two bubbles, the larger of which is distinctly movable. It is very unusual to meet with a plurality of bubbles in liquid cavities; but this case, and that represented at fig. 23, show that such instances do occur.

The porphyritic crystals of felspar are partly orthoclase and partly plagioclase. They are much altered and kaolinized.

The quartz crystals are in part rounded and are much corroded, containing the inclusions of the ground mass so characteristic of the quartz of quartz porphyries. A sketch of one of them is given at fig. 10. In the uncorroded portions the crystallographic form of the mineral is well preserved. Many of the quartz crystals are fringed with a thin border of mica.

The rock is a quartz porphyry on the border line of the granite porphyries.

No. 15. Sp. G. 2·60.—This specimen was taken from a tongue of the quartz porphyry dyke, above described, which protrudes into the adjoining rocks at right angles to the course of the dyke. The matrix of this specimen is perfectly compact, even when examined with a lens, but the rock does not differ in other respects from that just described.

M.—The ground mass is micro-felsitic, but between crossed nicols it has a spotted, mottled appearance, as if it were made up principally of imperfectly developed granules of felspar.

The porphyritic crystals of felspar are much decomposed and have to a considerable extent been converted into kaolin. Here and there patches of chlorite and a mineral that looks like pinite occur in them. Some of the felspars exhibit the characteristic twinning of the triclinic system.

There are several large micas in this slice of greenish colour in transmitted light, but they are much corroded and eaten into. The principal part of the mica present in the slice, however, exists rather in the form of micaceous matter than in well-shaped leaves or crystals, and is dappled over the ground mass in finely granular masses which exhibit no definite shape under the microscope, and only show dichroism, here and there, when in thicker masses than usual.

Gas inclusions are extremely numerous in the quartz. Liquid cavities with movable bubbles are less abundant than in the other slices of the quartz porphyry (Nos. 9—14), and they are of smaller size.

The slice is stained, here and there, red and yellow with ferrite, and contains a few small grains of magnetite or ilmenite.

The porphyritic quartz crystals are to some extent corroded, but on the whole they exhibit sharply defined crystallographic forms.

MM. Fouque and Michel-Lévy in their *Minéralogie Micrographique* give expression to the view that the porphyritic crystals of quartz in quartz porphyry belong to the first epoch of consolidation; the partial rounding of the porphyritic crystals and the inclusion of portions of the ground mass by the quartz they

attribute to the corrosion of the crystals due to mechanical and chemical action.[1]

A study of the rocks described in this paper has convinced me of the soundness of this view, and has satisfied me that the inclusions of the ground mass visible in the quartz crystals, in the specimens now described, are due to corrosion, or partial remelting, and not to imperfect crystallization consequent on rapid cooling.

The matrix of the hand specimen taken from the thin tongue protruded into the adjacent rocks is perfectly compact, even when viewed with a powerful pocket lens, whereas that taken from the body of the dyke appears, under the same lens, to be micro-granitic rather than compact,—a difference attributable, I presume, to the fact that the thin tongue cooled more rapidly than the main dyke. If the porphyritic crystals were formed after the intrusion of the quartz porphyry, one would expect to see a marked difference between those in the tongue and those in the main dyke, corresponding to the difference observable in the matrix of the specimens from the two localities. One would, also, expect to see inclusions of the ground mass more common, and crystallographic outlines less frequent in the former than in the latter. No such difference however is to be discerned. Sharp well-defined crystallographic outlines are not rare in the quartz of the specimen from the tongue; whilst the crystals in the main dyke are quite as much corroded as any in the tongue.

Figs. 8 and 10 of the plate attached to this paper may be usefully compared with fig. 43, p. 189 of MM. Fouqúe and Michel-Levy's work above quoted.

Felsites—Tushám.

Ten thin slices taken from five hand specimens have been examined. The specific gravity of the latter ranges as follows :—

No. 16	2·72
„ 18	2·76
„ 20	2·68
, 22	2·63
„ 24	2·77

The specific gravity of No. 24 is rather high, owing to the large amount of magnetite present in the rock.

The mean specific gravity of these five specimens is 2·71. The specific gravity of felsites according to J. D. Dana (Manual of Geology) ranges from 2·6 to 2·7 and according to B. von Cotta (Rocks Classified and Described) from 2·5 to 2·7; that of the specimens described in the following pages, therefore, agrees well with the above authorities.

Nos. 16 and 17.—A compact rock of dull brownish-red colour mottled with dark grey. With the aid of a lens, grains of free quartz are seen to be freely sprinkled about in the matrix. Some mica and minute specks of iron are also to be seen.

M.—The ground mass is micro-felsitic. Between crossed nicols the particles which show colour do not exhibit any tendency to that parallelism of arrange-

[1] See also Professor Judd's and Mr Cole's remarks in their paper on Basalt-glass. Q. J. G. S., XXXIX, p. 459.

ments which is so characteristic of slates. The matrix is, as is often seen in quartz porphyries, blotchy in appearance, and is not of that uniform structure generally observed in slaty rocks.

In ordinary transmitted light the ground mass appears to be formed of two magmas imperfectly blended together, which differ from each other sufficiently in colour to render the fluxion structure of the rock visible. The comparatively colourless magma appears to contain more quartz than the buff coloured felspathic magma.

In my paper on the gneissose granites of the North-West Himalayas, I noted an instance of grains of magnetite being involved in strings of red ferrite in a way to exhibit fluxion. (See fig. 14, Records, XVII, p. 72.)

In this slice a very similar instance occurs which I have sketched at fig. 9. The red ferrite has evidently been derived from the magnetite, and then, in the way suggested in my last quoted paper, the ferrite and the magnetite have been drawn out into strings during the subsequent motion of the mass. The ferrite has not, in this case, been formed *in situ* by the action of water flowing past the strings of magnetite. Fig. 9 should be compared with the description given in the paper referred to.

The slices contained a considerable amount of magnetite and a little hæmatite or göthite.

There are no porphyritic crystals of felspar, but crystals of quartz are numerous. They are in part rounded and corroded, though several of them present very perfect crystallographic outlines. The quartz contains numerous liquid cavities with movable bubbles and gas inclusions.

Thin rounded microliths are abundant, here and there, in the ground mass; they are either colourless, or of very pale green colour, and exhibit no dichroism, their optical properties being overpowered by the matrix in which they are imbedded. At times they radiate from a centre in a way that reminds one forcibly of the augite microliths of the pitchstone of Arran.

Nos. 18 and 19.—A dark grey compact rock with minute blebs of quartz visible here and there in it.

M.—The ground mass is micro-felsitic, and faint traces of fluxion structure may be made out in it. Porphyritic crystals of quartz are numerous. Some of them exhibit very perfect crystallographic outlines, but others are rounded and corroded. A few are in the form of prisms with pyramidal terminations.

The slice contains one or two fragments of schorl. What appear from their colour to have been crystals of hornblende are replaced by delessite or an allied mineral, quartz, and a little ferrite. The delessite is also dappled about over the slice.

A little magnetite is present, but it has for the most part been converted into red ferrite. There are one or two leaves of mica.

The quartz contains air inclusions and liquid cavities with movable and fixed bubbles.

Nos. 20 and 21.—A light grey compact rock with minute facets of quartz visible here and there in it. With a lens, some of these quartz crystals are seen to have very perfect forms, whilst others are rounded. Little cavities have

been created, here and there, by the decomposition and removal of the iron. The specimen very much resembles an acid lava in appearance.

M.—In general characteristics these slices are like those last described, except that they neither contain schorl nor delessite pseudomorphs; all trace of fluxion structure is also wanting. Some of the porphyritic crystals of quartz in these slices are very remarkable objects; instead of being clear single crystals, like those in the other slices, they contain strings of muscovite microliths, and are compounded of countless granules of quartz. This is all the more remarkable as the exterior crystallographic outline of these crystals is, in some cases, very sharply defined. In the field of the microscope these compound crystals have a striking resemblance to the quartz of such granites as the gneissose granites of the North-West Himalayas, in which the quartz exhibits a polysynthetic structure, and in which muscovite microliths are often abundant. The presence of compound crystal of this character is not inconsistent with, but is, on the contrary, explained by the theory that they belong to the first epoch of consolidation, for it is open to us to suppose that after the rock began to consolidate as granite it was put in motion and partially remelted.

Magnetite, converted in part into red ferrite *in situ*, is abundant in these slices, and numerous specks of it are present in the compound quartz crystals above described.

Liquid cavities with movable bubbles are plentiful in the quartz. In one liquid cavity I observed an inner liquid globule containing a violently active bubble. The liquid globule is probably carbon dioxide.

Nos. 22 and 23.—A dark grey compact rock, with minute blebs of quartz visible here and there. It weathers to a light brown the weathered portion forming a sort of rind more than a quarter of an inch thick. This is probably the rock called basalt in the Archæological Report (*foot-note, ante*).

M.—The ground mass is micro-felsitic, and the porphyritic crystals consist of quartz and felspar. Both plagioclase and orthoclase are present, but the crystals are not all fresh, many of the larger ones having been converted in part into a chloritic mineral. There are also some crystals which appear to be pseudomorphs after hornblende, the latter mineral having been wholly converted into viridite. The quartz crystals are, as usual, in part rounded and corroded; the other portions exhibiting sharp crystallographic outlines. A sketch of one of these crystals, taken from this slice, is given at fig. 8. This quartz was apparently at one time a prism with pyramidal terminations at both ends. The lower pyramid has been wholly eaten away, the top pyramid has lost its apex, and one side of the prism has been deeply corroded. The dotted lines in the sketch indicate the portions that have been removed.

Nos. 24 and 25.—A compact rock with minute blebs of quartz visible here and there. It has a mottled appearance.

M.—The ground mass is, as in the case of the other specimens, micro-felsitic. Fluxion structure is to be traced, but it is not marked.

Magnetite is very abundant in the slice, being present in well-shaped cubes and octahedrons. Many of these have been peroxidised into ferrite of a brilliant red colour without the loss of their characteristic crystallographic outlines. The

magnetite and ferrite give evidence, in the way they are grouped and arranged, of the flow of the ground mass.

These slices contain some leaves of a colourless mica, apparently muscovite, and a fragment of an altered mineral resembling hornblende.

Quartz is the only porphyritic mineral in this slice. It contains very numerous liquid cavities with bubbles and some gas cavities; also fine hair-like colourless belonites similar to those so often seen in the quartz of granite.

Tushám granite.

No. 26.—A coarse-grained rock extremely rich in schorl and in muscovite.

M.—Owing to the friable character of the rock, only a thick slice could be obtained, so thick that the felspar and schorl are quite opaque. The felspar is stained red and yellow with ferrite.

The quartz and felspar are very much intergrown, and some of the smaller crystals of the former exhibit hexagonal outlines, showing that they belong to the first epoch of consolidation, and that the granite exhibits a transitional stage between a normal granite and a quartz porphyry.

The quartz contains gas and liquid cavities.

No. 27.—This specimen generally resembles No. 26, but a black mica is substituted for muscovite. It is present in considerable abundance, but in small packets. Schorl is absent. This rock which comes from a different part of the hill to No. 26 is so friable that only a very thick slice could be made. It is so thick that no observations worth noting could be obtained under the microscope.

Hills near Tushám.

No. 28.—A fine-grained granite composed of felspar, quartz, and black mica.

M.—The felspar is of two, if not three kinds: plagioclase and orthoclase are both present, whilst the foliated mineral, described in detail further on, and which I regard as microcline, is abundant.

Quartz of both the first and second epoch of consolidation is present; the former is in polyhedric grains mixed up with or enclosed in other minerals. One caught up in felspar is a perfect prism with pyramidal terminations at both ends; whilst many others give more or less perfect six-sided sections. The quartz of the second epoch of consolidation is in large grains moulded on the other minerals. Globules, or rounded disks of quartz, are abundantly scattered through the ground mass. These disks are very characteristic of these rocks and of the Khának and Deosir granitoid quartz porphyries, to be described in the following pages. Sometimes they are seen to be merely thin disks without any tangible thickness; for they are seen to overlap each other, as in the south-east enclosure of fig. 5, or to lie one upon the other, as in the south-west enclosure of fig. 5, presenting in the latter case the appearance of an inclusion within an inclusion. Fig. 5, alluded to above, is a grain of quartz in this slice containing globulites, magnified 250 diameters.

Grains of quartz are often stuffed with these disks, as represented at figs. 7 and 15, both of which are taken from slices Nos. 28 and 29. The felsitic ground mass contains multitudes of them, and some, if not all, must belong to the second

epoch of consolidation, for they frequently dwindle rapidly in size as they approach the edge of porphyritic crystals of felspar. Fig. 6 is given to illustrate this tendency. The sketch represents a portion of the felsitic ground mass, the lower or southern margin of which abuts on a large felspar crystal which appears to have exercised an influence on the formation of the globular disks comparable with that of stratified rocks on sheets of basalt intruded into them; a dwindling in the size of the basaltic crystals being frequently observed towards the edges of intruded sheets.

That the globular disks, however, were not the last mineral to crystallize is clear, for masses of them are sometimes included in felspar crystals and are arranged in lines which conform rigidly to the crystallographic form of the felspar.

The mica appears to be biotite, and some magnetite is associated with it.

Gas cavities predominate over liquid cavities, but the latter are also present in some abundance. Many of the cavities are in polyhedric forms. At fig. 1 I have depicted one of imperfect hexagonal shape containing a cube of sodium chloride and a movable bubble.

Some of the quartz contains hair-like microliths of schorl.

This specimen approximates to a true granite.

No. 29.—A pinkish fine-grained granite. The pinkish colour is due to the rosy tint of much of the quartz. Some of the felspar is of dull greenish colour. Black mica is abundant.

M.—This appears to be a transitional form between a normal granite and a granite-porphyry.

The magma is composed of an extremely fine-grained mixture of quartz and felspar. The quartz is, for the most part, in rounded globules, which vary greatly in size, some being mere dots, whilst some here and there, especially when crowded closely together, present imperfect hexagonal outlines. They remind me much of the fish-roe grains of the Dalhousie gneissose granite.

In the ground mass, large crystalline fragments of felspar, quartz and leaves of dark mica, resembling biotite, are imbedded.

The mica was evidently formed after the micro-crystals of quartz; for it encloses granules of that mineral and it is moulded upon other grains of quartz, some of which present hexagonal outlines.

Orthoclase, plagioclase, and microcline are present; the latter, which is typically developed, is abundant. It occurs both as a component of the ground mass and in large crystals. None of the felspar presents external crystallographic outlines.

Rounded and hexagonal grains of quartz of moderate size, which form a portion of the magma, and crystals of felspar, are stuffed with minute rounded globules or disks of quartz, like eggs in the roe of a fish; whilst some of these globules of microscopic proportions themselves contain other globules still more minute.

Some of the quartz grains contain tabular inclusions of red ferrite, probably hæmatite, and to its presence I attribute the rosy tints of some of the quartz grains when viewed macroscopically.

One of the grains contains hair-like microliths that may be rutile.

Liquid cavities are numerous in some of the large quartz granules, whilst gas cavities are abundant in all. Some of the cavities contain a fixed bubble and deposited mineral matter of various kinds.

One of the felspars contains a leaf of muscovite.

The Khának hills 3 miles north-west from Tushám.

No. 30.—A fine-grained granite of whitish colour speckled with black. Black mica is abundant.

M.—Triclinic felspar crystals are numerous, and equal, or nearly equal, in number those of orthoclase. Microcline is not present. The quartz belongs to two epochs of formation. Moderately sized grains, many of which exhibit six-sided figures, and some of which are enclosed in felspar, are present, and also large pieces of quartz moulded on the other minerals.

The slice contains numerous small garnets, and some apatite. The quartz abounds in liquid cavities with movable bubbles, gas cavities and liquid cavities with gas bubbles. One enclosure is a very interesting one; it contains an abraded cube, apparently of sodium chloride, a globule of liquid containing an inner bubble, and other inclusions. The liquid globule seems to be carbon dioxide. Another enclosure contains a bubble and three crystals; whilst a third contains two bubbles, one a large gas one, and the other a small one of normal type.

Hair-like belonites are present in the quartz and microliths containing gas and other cavities.

The slice contains a good deal of magnetite or ilmenite for the most part associated with the dark mica.

No. 31. Sp. G. 2·62.—A dark grey coloured rock, in which crystals of felspar, quartz and black mica are thickly imbedded in a grey compact matrix.

M.—The ground mass is micro-felsitic and shows some feeble traces of fluxion structure. It contains orthoclase, plagioclase, and quartz porphyritically imbedded in it. The quartz is rounded and corroded as in quartz felsites. The slice contains numerous garnets.

Mica, brownish green in transmitted light, is very abundant. The leaves are grouped together, and some of them are well foliated.

This slice, Nos. 28 and 29, and the other specimens about to be described, contain a mineral regarding which I have felt considerable doubt. It is either colourless or has the faintest possible brownish yellow tint in transmitted light. It exhibits no dichroism and polarises in brilliant colours more suggestive of pyroxene than microcline. It presents a very finely foliated appearance, perfectly straight and parallel lines traverse it, and are so crowded together that about 200 of them may be counted in a single piece. Coarser but interrupted cleavage lines, in some specimens, cross these at an angle of about 82°. The negative axis is at a high angle (from 80° to 90°) from the fine lines. The mineral is superficially corroded here and there, after the manner of felspars, and the corrosions exhibit a strong tendency to run with the fine lines.

None of the pieces possess crystallographic outlines sufficiently definite or characteristic to help one to determine the nature of the mineral.

Between crossed nicols the mineral generally presents an unbroken sheet of colour, but occasionally the fine parallel striæ exhibit colourless streaks between the lines of colour, but this is apparently the optical effect produced by the cleavage planes on the transmitted polarised light, and is unlike the appearance produced by the multiple twinning of triclinic felspars. Moreover, in the case of triclinic felspars, the negative axis is at a comparative low angle to the twinning planes.

Pyroxene is sometimes found in granitic rocks (J. D. Dana's Maunal, p. 219) and diallage has been observed in some granulites composed of diallage, triclinic felspar, quartz, garnet, and biotite (Geikie's Text-Book of Geology, page 125). Viewed macroscopically, however, I can discover nothing in the hand specimens suggestive of pyroxene,—what is not quartz appears to be felspar.

In my paper "On the Microscopic Structure of some Dalhousie rocks" (Records, XVI, p. 131), I noted the occurrence of a fibrous felspar in those rocks, and quoted from Zirkel's Microscopical Petrology of the 40th Parallel a notice of a similar felspar which occurs in the American rocks.

The mineral now described differs from the Dalhousie one in that the fine parallel lines in the Arvâli mineral look less like fibres than cleavage planes; but still I think, on the whole, that the mineral before me can only be a variety of microcline.

The slice contains magnetite or ilmenite. A microlith, apparently of quartz, contains a liquid cavity, with a movable bubble.

The quartz contains the usual liquid cavities.

The microscopic examination of this slice shows that the rock is a quartz porphyry approaching to a granite porphyry.

No. 32.—This specimen closely resembles the last, but the amorphous paste is, perhaps, less abundant.

M.—Under the microscope this rock presents much the same appearance as the last. The porphyritic crystals of quartz and felspar are rounded and corroded, and contain inclusions of the ground mass. The fibrous felspar (microcline) is abundant. Flakes of mica are scattered through the ground mass in great numbers.

Nigána hills, 7 miles south from Tushám.

Nos. 33-38.—A pinkish rock closely resembling a granite. The felspathic ground mass is in this specimen at its minimum.

M.—These slices present the general characteristics of the Khának rocks. Liquid cavities containing vacuum and gas bubbles are abundant. Some of the cavities are of hexagonal shape. A great many of them contain deposited minerals as well as bubbles. One, containing three cubes and a bubble, is depicted at fig. 2. I also observed a microlith containing a stone enclosure.

Microliths, probably of schorl, are abundant in the quartz.

As in the other Khának specimens, globules of quartz, some of which are of imperfect hexagonal form, are abundant.

Deosir, an isolated hill, about 4 miles south-west from Bhiwáni

Nos. 39-41.—A fine-grained granite of grey colour composed of quartz, felspar, and black mica. Viewed macroscopically this appears to be a perfect granite.

M.—Under the microscope, this rock is seen to possess a micro-crystalline ground mass, in which large crystals of felspar, quartz, and biotite (?) are imbedded. The ground mass consists of a felspathic base in which myriads of quartz globulites are scattered about. Most of them present more or less rounded outlines, but some are roughly hexagonal or four-sided in shape.

There are some micro-garnets, and a little schorl, blue in transmitted light, is seen in one of the slices.

Porphyritic crystals are present which exhibit crystallographic outlines in part, whilst other portions of them are rounded, and contain inclusions of the ground mass.

Plagioclase and orthoclase are both present. The latter is very glassy and is undistinguishable from sanidine.

Liquid cavities with bubbles are very numerous in the quartz, and many of them contain deposits of sodium chloride or other cubic salt. One containing a cube of the latter also contains a red liquid globule with an inner bubble. In some, as in the case depicted at fig. 3, the crystalline deposit nearly fills the whole cavity. In another case, see fig. 4, gas and a crystalline deposit are included in the same cavity. These examples appear to indicate conditions of intense heat and great consequent solvent capacity in the liquid and gas. Some of the cavities are of rough hexagonal shape.

The ground mass contains numerous dots of opacite. Fine hair-like microliths are common in some of the quartz.

Hissar City Wall.

Nos. 42-43.—The wall of the town of Hissar is built of blocks of rock from the neighbouring hills of Khának or Nigána. The thin slices examined do not differ from those described in the preceding pages.

Conclusion.

When I commenced the microscopical examination of the rocks described in the preceding pages, I though it probable that somo affinity would be detected between the Dosi syenitic granitoid gneiss and the granitoid rocks of Nigána, Khának, and Deosir, but they proved to be altogether different.

In the Dosi rock hornblende is a prominent feature, whereas in the rocks with which it has been compared, there is scarcely a trace of that mineral.

The Dosi rock, moreover, is of granitic structure, whereas the Khának rock, and its allies are quartz porphyries more or less approximating to, but never becoming, true granites.

In point of age there is probably a wide gulf between them. What the precise geological age of the Khának group may be, it is impossible to determine from the examination of the Tusbám region alone, as the Khának rocks and their allies form isolated hills—small islands as it were—rising from a sea-like expanse of post-tertiary sandy soil, the long swelling waves of which, formed into a series of crests and troughs by the prevailing westerly winds, break like the swell of the ocean on their rocky shores.

Whether the Dosi syenitic granitoid gneiss is or is not an igneous rock is a question which must remain for the present an open one. It has its allies doubtless further south, and the question must be decided in connection with them. Certain it is that the Dosi rock contains internal evidence of having been reduced by aqueo-igneous agencies to a fused condition, and it does not differ in internal structure from some Scotch eruptive rocks with which it has been compared. These circumstances, however, are not in themselves sufficient to determine the question. The examination of the Delhi quartzite, detailed in this paper, shows that this rock also, regarding the sedimentary origin of which I presume there can be no doubt, was subjected to intense aqueo-igneous heat and reduced to a plastic condition.

The microscopical examination of the Delhi quartzite is most instructive, for it shows that whilst we have at the one end of the metamorphic scale such rocks as the micaceous schist intercalated with unaltered limestones of the carbo-triassic series, alluded to in my paper on the gneissose granites of the North-West Himalayas, the metamorphism of which has evidently been brought about by aqueous agencies which required little heat for their accomplishment, at the other end of the scale we have very ancient rocks like the Delhi quartzite which have been subjected to intense plutonic heat.

The Delhi quartzite, moreover, shows that evidence of fusion, taken alone, is not sufficient to enable us to say definitely whether a rock which exhibits it is an eruptive or a metamorphic rock.

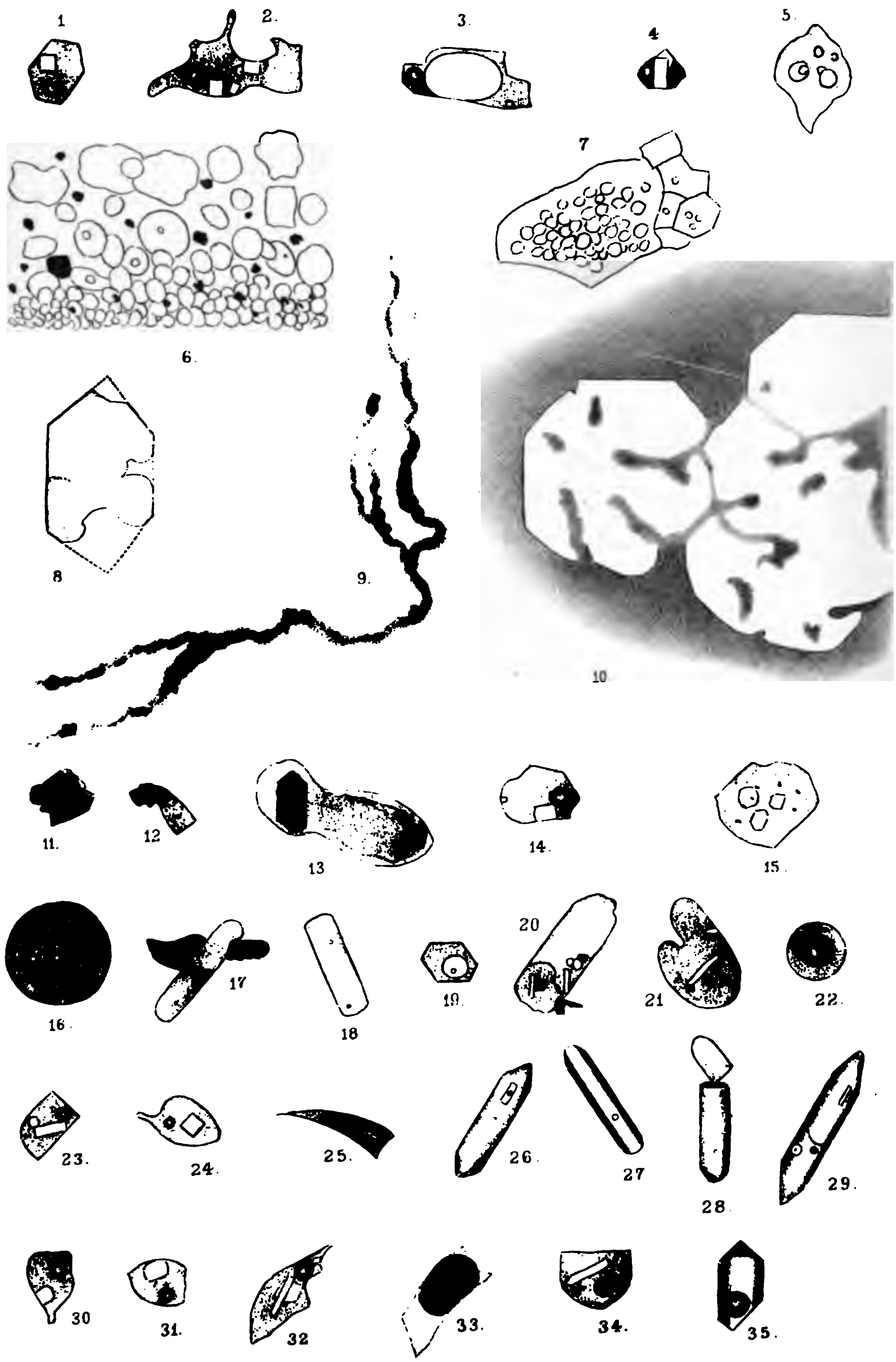
Evidence of fusion, however, is a point, the significance of which can hardly be over-estimated. Combined with other evidence which would not in itself be conclusive, it may place the eruptive character of a rock beyond doubt; whilst, in doubtful cases, evidence of igneous fusion would, I think, narrow the issue to be determined to the question whether the rock under examination is an igneous one or a metamorphic rock of extreme geological age.

Plutonic heat sufficient to reduce such a rock as a quartzite to a fused condition must have occurred at a great depth, and a rock so deeply buried must have required ages to come to the surface. Hence evidence of igneous fusion in a metamorphic rock affords a strong presumption of great geological age.

The difficulties which some geologists feel in believing in the existence of other than archæan metamorphic rocks may possibly arise, it seems to me, from not sufficiently discriminating between plutonic metamorphism, like that exhibited by the Delhi quartzite, and the hypo-metamorphism of such rocks as the carbo-triassic mica schist, previously alluded to, which may be produced by aqueous agencies near the surface, without much heat, and which does not connote archæan age.

But to return to the Arváli rocks. Whilst I do not consider it desirable, for the reasons given above, to pronounce a definite opinion regarding the Dosi syenitic granitoid gneiss, on the other hand the microscopic examination of the Tushám, Khának, and Deosir rocks has satisfied me that many of these, which I previously regarded as probably of metamorphic origin, are really eruptive rocks.

The chiastolite schists and the indurated clays on the eastern flank of Tushám are of course sedimentary beds; but the rocks which compose the centre and



J. Schaumburg, Lith.

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the western flank of the hill prove to be felsites or micro-quartz-porphyries, which contain internal evidence of their eruptive origin in the shape of fluxion structure and other structural peculiarities.

The Tushám rocks are penetrated by granite bosses and veins and by quartz porphyry dykes which are undoubtedly intrusive.

A little hill close to Tushám and the hills of Khának, Nigána, and Deosir are evidently closely allied to the granite, the quartz porphyry, and the felsites of Tushám. Viewed macroscopically these rocks at first sight look like granites, but the aid of a pocket lens enables one to detect more or less amorphous paste in nearly all of them. Under the microscope they are seen to be quartz porphyries, which shade towards the granite porphyries on the one hand, and towards the felsites on the other. Indeed the felsites of Tushám are micro-quartz-porphyries. Under the microscope they are seen to be of precisely the same structure as the Tushám quartz porphyry; the only difference being that in the former the grain is of microscopic fineness, and the porphyritic crystals extremely minute; whilst in the latter, the porphyritic crystals are of large size, and the distinction between them and the amorphous ground mass is visible to the unaided eye.

The Nigána, Khának, and Deosir rocks are also essentially quartz porphyries in their structure, but the porphyritic crystals are in size intermediate between those of the quartz porphyries and the felsites of Tushám. The amorphous paste (ground mass), however, is relatively small in amount, and the resulting rock approximates in appearance to a granite. That they are all eruptive rocks, and all more or less connected with each other, I see no reason to doubt. Fluxion structure, and the presence of minerals of the first and second epochs of consolidation, the former of which have been partially rounded, corroded, and eaten into, as in figs. 8 and 10 of the plate attached to this paper, seem to me to offer decided indications of their eruptive origin.

DESCRIPTION OF THE PLATE.

Fig. 1.—Á liquid cavity of imperfect hexagonal form, containing a movable bubble and a cube of sodium sulphide. Granitoid quartz-porphyry from hill near Tushán. Slice No. 28.

Fig. 2.—Liquid cavity containing deposited minerals and a bubble. Slices 33—38. Granitoid quartz-porphyry. Nigána hills.

Fig. 3.—Crystalline deposit nearly filling a liquid cavity. Granitoid quartz-porphyry. Deosir. Slices 39—41.

Fig. 4.—Crystalline deposit in gas cavity. *Ib.*

Figs. 5, 6, and 7.—Rounded granules and disks of quartz scattered through the ground mass (fig. 5), and enclosed in quartz grains (figs. 5 and 7). Slice No. 28. Granitoid quartz porphyry. Hill near Tushám.

Fig. 8.—Quartz crystal in part rounded and corroded. Slices 22 and 23. Felsite. Tushám.

Fig. 9.—Grains of magnetite involved in a string of red ferrite. Slices 16 and 17. Felsite. Tushám.

Fig. 10.—Quartz crystal partially rounded and corroded. Slices 9—14. Quartz porphyry. Tushám.

Fig. 11.—An air bubble attached to minerals. Slices 5—7. Delhi quartzites.

Fig. 12.—Opacite drawn towards and attached to a microlith, *Ib.*

Fig. 13.—An opaque crystal embraced by a flake of mica. *Ib.*

Fig. 14.—Liquid cavity with the bubbles (right hand one is movable) and a corroded crystal of sodium chloride. Slices 9—14. Quartz porphyry. Tushám.

Fig. 15.—Rounded disks of quartz and dots of opacite enclosed in a quartz grain. Slices 28 and 29. Granitoid quartz porphyry. Hill near Tushám.

Fig. 16.—Coloured stone enclosure containing four fixed bubbles in the quartz of the Dosi syenitic granitoid gneiss. Slices 1—4.

Figs. 17 and 18.—Microliths containing shrinkage cavities. Opacite has formed on that in fig. 17. Slices 5—7. Delhi quartzite.

Fig. 19.—Liquid cavity of hexagonal shape containing a globule of liquid carbon dioxide and inner movable bubble. Delhi quartzite. *Ib.*

Figs. 20 and 21.—Microliths (20 of quartz and 21 of mica) which have caught up micro-crystals and opacite. Delhi quartzite. *Ib.*

Fig. 22.—Air or gas bubble surrounded by a ring of coloured mineral matter. Delhi quartzite. *Ib.*

Fig. 23.—A liquid cavity containing a crystal and two bubbles; the right hand one being a movable gas bubble. Dosi syenitic granitoid gneiss.

Fig. 24.—Liquid cavity containing bubble and crystal from the quartz of granite invading lower silurian rocks. Aberdeen.

Fig. 25.—Enclosure containing gas. *Ib.*

Figs. 26, 27, 28, and 29.—Micro-crystals containing liquid cavities and shrinkage cracks in the Aberdeen granite referred to under fig. 24.

Figs. 30, 31, and 32.—Liquid cavities in the Dosi syenitic granitoid gneiss in which crystals have been deposited on cooling. The cavities also contain bubbles.

Fig. 33.—A gas inclusion in a liquid cavity. *Ib.*

Fig. 34.—Another liquid cavity in which a crystal has been deposited on cooling. *Ib.*

Fig. 35.—A liquid cavity in quartz which has taken the shape of a quartz crystal. The enclosed liquid contains a movable bubble. *Ib.*

Section *along the* Indus *from the Peshâwar valley to the Salt-range, by* W. WAAGEN, PH.D., F.G.S.[1]

Having just returned from a little trip from Kálabágh up the Lun Valley to Kohat, and from there over the Kotal Pass into the Peshâwar valley, then back over the Meer Kulan, Pallosi, and Sundully Passes to Shadipur and down the Indus to Kálabágh, I hasten to communicate to you some of the results, as far as I am able to point them out here in the field.

[1] The figured section, with the brief description now published, was communicated to Dr. Oldham in the form of a letter some 12 years ago, when Dr. Waagen was attached to the Geological Survey of India. As an accurate representation, so far as the scale would admit, of a most inter-

One of the most interesting parts of the whole excursion certainly was the returning road down the Indus, as this exhibited an uninterrupted section from the oldest to the youngest formations of the whole country, and it is principally this section, of which I send you enclosed a drawing, which I intend to describe more accurately.

Starting from Julozai in the valley of the Cabul river, one has to traverse first a rather extensive plain, consisting entirely of debris, mostly of a red sandstone and marl mixed with fragments of black slate and quartzitic sandstone. As soon as one reaches the skirts of the hills down in a little ravine, a yellowish limestone with great masses of greenish flaggy shales and slates below crops out. The slates continue, changing their colour slowly into black, and then mixed with dark, extremely hard quartzitic sandstones. After about 2 or 3 miles marching, down in a deep glen, suddenly a light-coloured limestone appears, as if dipping under the slates, which are exposed to an enormous extent on both sides of the glen. After a short search, nummulites were detected in this limestone, which is, however, not more than about 10 feet in thickness, being then already followed by red sandstones and shales, nearly quite vertical. Though the red colour prevails in these rocks, there are also some thick pale green bands in it, which, however, do not influence the general red aspect of the whole formation. The thickness of this formation is very great, though not so much as that of the slates, and at several horizons in it thin bands of nummulitic limestone are to be met with. The road winds then up out of the bottom of the ravine, and then again nummulitic limestone appears, here nearly horizontal, forming a crest, and apparently lying regularly above the red formation. The nummulitic, however, is lost soon again, and the red sandstones and shales, here locally almost vertical, are the rocks, over which the path winds up further on. Descending into the glen on the other side of the pass, the red formation is replaced by dark shales, in some layers filled with the impressions of fossils, among them very numerous impressions of nummulites. They rest upon thick hard grey limestones, in which nummulites could not be detected, though they may yet belong to this formation. The bungalow lying on the scarp of the glen is built on these limestones. Below them follow first again dark shales, then a light-coloured flaggy limestone, contorted like the Flysch along the northern base of the Alps, then again shales, and then a thick zone of white and light grey quartzites, resting on a formation of greenish or greyish slaty shales of several hundred feet in thickness. No trace of fossils could be detected in all those layers. Below this, grey limestones in thick banks are sticking out, but also here fossils are extremely rare, and no characteristic species was obtainable. Sections of shells are visible on the weathered surfaces, and in some places I saw Entrochi of a little sharp angular Pentacrinite. Under these again a thick mass of brownish coloured slaty

esting section, it is well worthy of record; showing a continuous section of the immense sequence of tertiary rocks lying between the Himalayan elevation and the outlying remnant, now left in the Salt-range, of what were probably the ancient fringing deposits of peninsular India. The interpretation given of some points of the section may perhaps be open to question, but this scarcely interferes with the admirable view presented of the prodigious movements that have affected this enormous accumulation of tertiary strata. The elevation of the Peshawar plain at Attock is only 1,100 feet, and that of Kálabágh about 700.—H. B. M.

shales is lying, with lenticular portions of a beautiful oolitic grey limestone in it, then, just above the village follow white lithographic limestones without any fossils, then again slaty shales.

After having crossed the valley of a little river the way again ascends to the Pallosi and Sundully Passes, which both in reality form only one Pass, crossing the range of mountains of which the Niláb Gash is the highest point in British territory. On the north foot of the hills, yellow marly limestones, dipping at a low angle to the north, and containing casts of a large Lucina and some Gasteropods appear, then follow compact nummulitic limestones in great thickness, dipping here to the south, but further on much contorted. In fact the whole range chiefly consists of these limestones, and only in the deeper cuttings of valleys or ravines, older formations appear. So, looking down from the height of the Sundully Pass, a rather thick system of limestones, sandstones, and shales, on the whole of a brownish-yellow aspect, is observable. We were prevented by rain and the short daytime from going down and examining the beds closer. But from fragments found before in the river, and from the beds observed by Mr. Wynne at another locality, it seems that cretaceous and jurassic, certainly mesozoic, deposits are here represented. On the other side of the valley nothing of those formations is observable, but instead of that a red band runs along the foot of the steep scarp of the nummulitic limestone.

The southern slope of the range is very steep, and the first descent is entirely occupied by nummulitic limestone; then there is a sudden change in colour, and the whole country appears as if looked at through a red glass. In the beginning just at the foot of the hills, between the purplish-red layers, a few bands of yellow marly nummulitics are still observable, but they are only few in number and very thin. Further on purplish-red sandstones and marls compose exclusively the rocks along the road, only sometimes there appears a greenish zone; the layers are fearfully contorted and dipping in every direction. A short distance before reaching Shadipur the red colour is lost again, thick soft grey sandstones here cropping out, only seldom interrupted by a purplish marl band.

At Shadipur I took a boat, and during four days going down the river I observed the following section. At Shadipur the grey sandstones appear along the river bank, dipping to the south, then the purplish-red series comes in again inexpressibly contorted, and two or three miles further down a band of nummulitic limestone, with vertical bedding, crosses the river. Behind this a little valley, filled up with unconformable conglomerate, comes down to the river, and conceals the junction between the nummulitics and the next series, the same grey sandstone with a few purplish marl zones, upon which Shadipur is built. The layers, however, are here nearly all vertical, sometimes inclined a little to one or the other side. This again lasts for several miles, the contortions become less strong and so better visible; suddenly thick marly layers of a red colour appear, mixed with rather thin beds of grey sandstone. To mention all the contortions of these and all the following layers is utterly impossible, and I can in this respect only refer to the drawing, which I have made after nature, and which may give a general idea of the features of stratification. A comparatively short distance further on, the red marls and grey sandstones are checked by a fault against a

very extensive series of purplish marls with subordinate but often very thick grey sandstones, about in the middle of which Kushialgurh is built on a sandstone reef.

This purple series lasts yet for a long distance below Kushialgurh, but then it finishes at a little valley which comes down to the river, on the other side of which suddenly red marls appear, dipping under a rather low angle to the south. The sandstones between these marls are grey, as elsewhere in the Indus section. The colour of the marls, going further down the river, rapidly changes into brick-red, and near the rapid at Kasab the red colour is most striking. A short distance below Pres, the river turns to west 30° south and runs for about 6 miles in a beautiful channel nearly in the strike of the beds, which is with a very remarkable constancy from Shadipur down to Mirzapur at the mouth of the Sohán river, west 20° south —east 20° north. The river flows for a very long way through the red series, only at the short turn before arriving at the last rapid, the colour of the marls changes suddenly into orange and green, and then follows a very thick pale yellowish-grey sandstone in enormously thick beds, only rarely interrupted by orange marls. In the upper region the sandstone contains layers of conglomerate, consisting of pebbles of beautiful crystalline, metamorphic or eruptive rocks. The conglomerate beds become more and more numerous, and at last the rock changes into a very extensive mass of conglomerates, in which limestone pebbles are nearly entirely unknown.

Further on the thick sandstone, which I shall call Dungote Sandstone, after the Dungote Hill, which is entirely formed of it, comes out again, and below it the orange series, both dipping to the north, then a short span of very contorted orange beds, and then again the conglomerates, faulted against the former. The bedding now quickly changes to nearly horizontal, about Makhud. Below Makhud the Dungote sandstone comes a third time above the level of the river, sometimes containing a bed of conglomerate, the decomposition of which has covered the whole country with a rather thick sheet of perfectly rounded pebbles of crystalline rocks.

Coming near the mouth of the Sohán river in the vicinity of the hill tract in connection with the Salt-range, the stratification of the rocks is again disturbed, the layers are turned up, dipping to the north, and the orange series appears below the Dungote sandstone in a broad zone. A fault just below Dungote Hill brings the sandstone again down to the level of the river; a little further on, after several faults, the orange series forms the sides of the cutting the river has made through the hills, down to the Lun river valley. Below this, the rock-salt, gypsum, and red marl of the Kálabágh and Mari hills form the river bank. In the Kálabágh hill a part of the orange series lies unconformable upon the salt and gypsum, and above this again unconformably a thick conglomerate, consisting nearly exclusively of calcareous pebbles. Kálabágh itself stands upon highly tilted layers of sandstone with conglomerates of crystalline pebbles.

Such is in rough outline what I have seen. The more difficult task, however, is to arrange all the divisions I have distinguished into a chronological scale, and to discuss their relations to each other. I begin with the undoubtedly youngest of them: the

(1) Unconformable Conglomerate. This formation is spread over the whole Rawal Pindi plateau in more or less extensive patches, and I have marked it in the section at several points: at Kálabágh, below Res, below and above Kushialgurh, and below Shadipur. It nearly always consists chiefly of calcareous pebbles. It has partaken in the disturbances of the older beds, so far as I know, only at Kálabágh, where it is erected vertically in some places. Of about the same age, or a little older, may be certain clayey sands of a white or yellowish colour, which I have marked below Kushialgurh.

Undoubtedly older than No. 1, but following immediately below it in the scale of our section, is the

(2) Conformable Conglomerate. This formation shows the best development in the hills above Makhud, where it is exposed to an enormous extent all along the river. It appears again near Makhud itself, but nowhere again to the south or to the north. It is chiefly consisting of crystalline pebbles, and is intimately connected with the underlying sandstone, is disturbed entirely in the same way as this, and actually passes down into

(3) Dungote Sandstone. A pale yellowish-grey more or less soft sandstone of about 2,000 feet in thickness, alternating commonly with layers of conglomerate in the upper and orange marl beds in the lower part. A part of the hills above Makhud and the greater part of the Dungote hill range is formed by this sandstone; its most extensive development is, however, further west from the Indus.

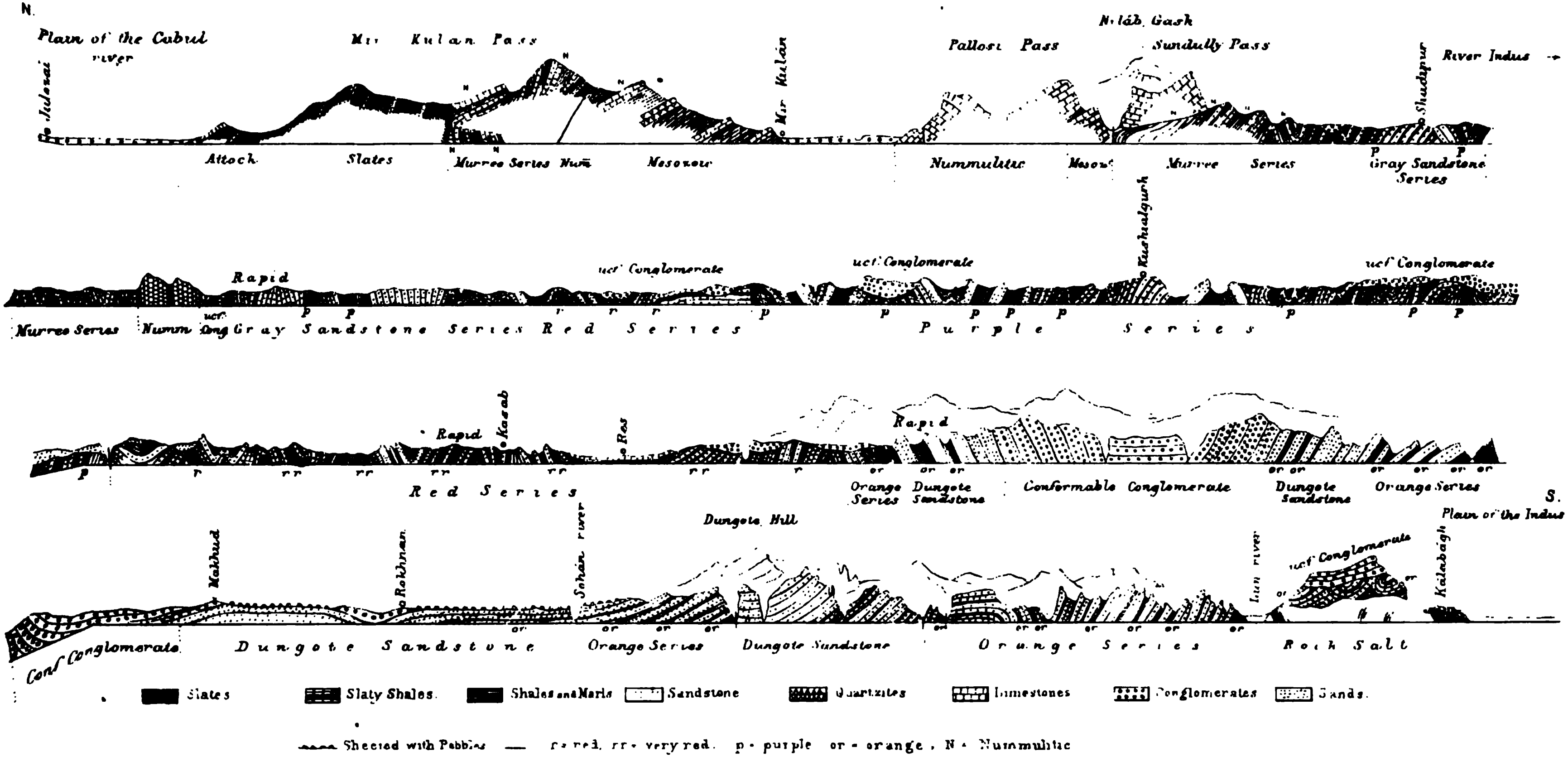
(4) Orange Series. There is a perfect transition from the sandstone above into this series. The principal rocks are grey sandstones interstratified with partly very thick beds of often very bright orange and grey coloured marls. This series is found resting unconformable upon the rock-salt and gypsum at Kálabágh; all the hills between the Dungote ridge and the Lun valley consist of it; it appears north of the Dungote hill, and north and south of the hill range above Makhud: everywhere in intimate connection with the Dungote sandstone. The thickness of this series is only in some parts considerable.

(5) Red Series. By alternation of red with orange beds, the series before described passes into this. The marls are here very much prevailing over the sandstones, and of a bright brick-red colour. In our section this series is only represented north of the conglomerate hills near Res and Kasab, and for a short distance between Kushialgurh and Shadipur. At the latter place it passes down into the

(6) Grey Sandstone Series, consisting of thick grey sandstones with rare marl beds of grey and purple colour. This series occurs at Shadipur, and to a greater extent below this village. Its relations to the next bed are nowhere sufficiently clear to determine from a stratigraphical point of view the age of this series, but as in the next division already nummulites occur, there is no doubt that it must be older than all the rocks as yet mentioned, and one can therefore safely suppose that the grey sandstone with purple marls passes down into the

(7) Purple and Murree Series. I put these two series down together, though their appearance is not entirely identical, as both series contain in small bands nummulitic limestone. Their chief difference consists in the sandstones, which are in the former grey, in the latter purple. The purple series as developed in

SKETCH SECTION FROM JULOZAI IN THE CABUL RIVER VALLEY TO SHADIPUR AND FROM THERE ALONG THE INDUS TO KALABAGH.



the country round Kushialgurh shows no nummulitic band; but in the direct strike of the beds, in the vicinity of Goorgoorlot Sir, I collected a great quantity of nummulites in them. The Murree series with purple sandstones is developed north and south of Shadipur, and in the centre of the Mir Kulán Pass. The stratigraphical relations of this series to the nummulitic limestone are extremely difficult: its layers stand vertical at the side of nummulitic limestone south of Shadipur; they seem to dip under the latter at Sundully Pass, and lie above the oldest nummulitics on the Mir Kulán Pass. That their position is certainly not below the great mass of compact nummulitic limestone is shown clearly by the Pallosi Pass, where the limestone lies immediately above the mesozoics without the Murree series between. It is therefore for me no doubt that the Purple and Murree series are the youngest nummulitics passing up without interruption into younger tertiary and diluvial deposits.

(8) Nummulitic Limestone. Developed to a great extent in the Niláb Gash range, the southern part of which is pushed over the Murree series in a very similar manner as the Alpine limestone is pushed over the Flysch along the northern foot of the Alps. The lowest division of the nummulitics consists of brown shales, which are exposed at the Mir Kulán Pass. In this latter range the lower nummulitic limestone (above the shales) does not come into the section, but is well developed further to the west.

(9) Mesozoic. The rocks and whole development of these formations is so strange in this country, that I must abolish for the present any attempt to go into particulars about them. That those beds are mesozoic is not doubtful, as the want of nummulites and the fragments of belemnites in fallen pebbles in the Pallosi pass very strongly indicate.

(10) Attock Slates. As neither fossils are found, nor do the stratigraphical relations reveal anything, I am utterly at a loss as to the determination of their age. About the age of the last formation, the

(11) Rock Salt, I shall report another time.

On the selection of Sites *for* Borings *in the* Raigarh-Hingir Coal-field. *First notice, by* WILL. KING, B.A., D. Sc., *Officiating Superintendent, Geological Survey of India.* (With a map.)

I.—The Country and the Rocks.
II.—Division into Boring Areas.
(a) The Lillari Valley Tract.

I.—The country selected for this exploration lies about 22 miles north-northwest of Sambalpur, being partly in the Raigarh and five other smaller zemindaries of that district, and partly in the Hingir dependency of the Gangpur tributary state of Chutia-Nagpur. Its geology and much of its coal capabilities have been already described[1] by Mr. V. Ball (late of the Geological Survey); and the occurrence of coal was known[2] to Captain Saxton so far back as 1855.

[1] Rec., G. S. I., IV, pp. 101-107 (1871); VIII, pp. 102-121 (1875); and X, pp. 170-173 (1877). Also, Manual of the Geology of India, Part I, Chap. V, p. 128; Chap. IX, p. 208; and Part III, Chap. II, p. 89.

[2] A Statistical Account of Bengal (W. W. Hunter), Vol. XVII, p. 190.

Although more than twelve years have elapsed since Mr. Ball's first report was made, it is only now that the more practical development of this field is being taken in hand owing to the renewed proposals for increased railway communication between the Central Provinces and Calcutta. It will therefore be some satisfaction to this geologist, after his unpromising labours in such an isolated and difficult tract as this is, as also to his predecessors in this field, to know that this line of railway will traverse the Hingir plateau. It is practically to meet the requirements of this section of the Bengal and Nagpur Railway[1] that the present boring reconnaissance is being made.

In the main, this region is a low irregular plateau or upland, the surface of which has a general very easy slope from north to south, with a slight depression or hollow in its southern half, along which the trace of the railway line runs. Except at a few points such as where the railway enters on it from the Raigarh or Bilaspur side and leaves it in the Rajpur or Ib river valley, the plateau is edged on all sides, but that to the north-west by a tolerably well-marked escarpment of from 150 to 400 feet in height. There are further flat-topped hills in the interior and in the north and eastern portions which attain an elevation of over 1,500 and 1,900 feet above the sea. The large village of Hingir is near the centre of the plateau at about 1,200 feet; and the railway trace enters on the western side at 741 feet, runs up to 942 feet in the middle, and leaves, on the Rajpur side, at 790 feet above datum (Karachi, M. S. L.), passing about 4½ miles due south of Hingir. The proper plain below the escarpment slopes away gradually; on the south side, towards Sambalpur; on the east, to the Ib and its tributary the Baisandar; but to the south-westward, there is at first only an extremely narrow low-level valley, shut in by a long north-west—south-east ridge of crystalline and transition rocks, outside of which is the proper low country of Raigarh and Bilaspur. The drainage system is included between the Kelo tributary of the Mahanadi on the west and the Ib on the east; the plateau itself being mainly watered by the Kur, Oira, and Bagdia nalas on the one side and the Lillari and Dulunga rivers on the south and north-east.

The different rock formations are very clearly displayed in the surface features of the country. The plateau and escarpment are of sandstones and other beds which Mr. Ball classed as 'Upper Sandstones' or 'Hingir Beds,' preferring to leave their position in the Gondwana series rather an open question, his tendency in his latest notice[2] being to range them in "two distinct groups, one containing fossil plants which serve to correlate it with the Kamthi-Raniganj group, the other being probably of Mahadeva age." Beneath these Upper Beds or Kamthis and forming the base of the escarpment, or a low terrace at its foot as well as the low country for some distance out, all round the plateau except to the north-west, are beds of the Barakar formation, with perhaps two or even more coal seams. The thickness of the Barakars appears to range from 200 feet at the lowest on the

[1] I am indebted for much of my estimates of thicknesses, &c., of the strata in this region to an Index map and section of the railway surveys. The 1-inch map of the Topographical Survey is very poor, full of misplacements of village names, and occasionally out in the courses of the smaller rivers.

[2] Manual, Part III, Chap. III, p. 89.

south-west side of the field, to 600 feet or more on the northern edges. Beneath these again lie the Talchirs which crop out at various places in the outer low country.

So far, the definition or display of these three sub-divisions of the lower Gondwanas is perfectly clear; but, as with my former colleague, I am also unable to draw any hard-and-fast line of demarcation between the top of the Barakars and the bottom of the Kamthis. At the same time, as far as the present enquiry goes, it will be possible to recognise with approximate accuracy strata of the two formations in such borings as may be made through them.

It may seem almost unnecessary to dwell further on any but the Barakar rocks, which, as holding the coal seams, would appear to be those alone requiring search by boring, more particularly as all the rocks have been already described by Mr. Ball. The exposure of the Barakars is, however, often so very narrow and shut in along the south-western border, and the seams are apparently so near the surface, and thus possibly disconnected by denudation where their area is wider, that the contingency of having to bore through the lower part of the Kamthis must not be overlooked.

My further examination of these upper beds shows that they are separable, over most of the field, into three marked bands or zones, the uppermost of which is a set of thick-bedded sandstones, more particularly seen in the higher flat-topped hills of Hingir. Beneath these comes a varying thickness of softer and less harsh-surfaced strata, with seams and patches of small pebbles and gravel, generally of reddish colours, making up much of that part of the plateau crossed by the railway line. Lower still, are more indurated coarse sandstones of red and purple colours, but weathering brown; with which are associated frequent seams and even beds of hard red clays and shales full of characteristic Kamthi species of *Glossopteris*, *Schizoneura*, and *Vertebraria*. The thickness of each of these bands varies a good deal; and at times the middle one seems to disappear, while the upper or lower one thickens out.

The red-clay zone is fairly persistent throughout; and, as immediately overlying the Barakars, and being occasionally sufficiently denuded to present no insuperable thickness against the boring tool reaching the possibly underlying coal measures, it is of considerable interest. Its thickness may be as low as 150 feet along the south-western edge of the plateau, and this may increase to 300 feet on the north-eastern border.

The Barakars are, fortunately for purposes of recognition in different parts of the field, also marked by distinguishable bands of strata. Their upper portion consists of a decided zone of brown-weathering ironstone flags and thin beds, so characteristic in the south-west fringe of low country as to have been particularly noticed by Mr. Ball who, in one part of his report, says "the position of the Barakars is marked by the ironstones." The zone is not very thick here, perhaps hardly 40 feet at the most; and it is constant all down the Sambalpuri-Dibdorah valley as a step or short terrace which widens out at the southern end about Katrapali, Durga, and Singarpur. Thus far, it forms a distinct band at the top of the Barakars; but to the eastward, as it rounds into the broader open country of Lakanpur and Rampur, brown flaggy beds occur more distributed through a

greater thickness of these strata which still hold the terraced contour into the Baisandar valley. A second and lower band, but of purple and reddish ironstones, also noted by Mr. Ball as a "tessalated ironstone," occurs in the lower half of the Barakars, being well displayed in the Rampur country, and again slightly in the Dulunga valley.

The upper zone is, however, both stratigraphically and industrially the most important; for it gives a horizon above or below which a great deal can be surmised as to the conditions of the coal-measures themselves, or the series overlying them, while it is from these beds that the principal supply of ore is obtained for the iron furnaces so common over this belt of terraced land.

Taking the coal outcrops in order from west to east, the first and indeed the best exposures are in the Oira or Hingir river near Dibdorah, where there are two outcrops which, as the dip is low, may really be parts of one and the same seam. At any rate, the upper part of this seam, or the uppermost, if there be two of them, can hardly be so much as 40 feet below the upper ironstones, the interval being of thick-bedded coarse felspathic free-stones. The outcrops indicate a good thickness of coal and carbonaceous shale, Mr. Ball having cut through 6 feet of coal in one, while I sunk a pit 12 feet deep in the other without reaching the bottom, of which 4 feet was fairly good coal.

The next coal was found by Mr. Ball in the Bagdia nala near Lakanpur, the top of the seam being alone exposed; it is associated also with thick-bedded sandstones just below the upper ironstone band.

Still further east, in the valley of the Lillari river, are some four or five outcrops, the uppermost of which, between the villages of Kaliabahal and Chowdibahal, occurs close up to the ironstone band associated with thinish beds of grey and buff sandstone. The upper part of the seam, of which I ascertained 4 feet 6 inches at least of good coal, is well exposed in the bed of the river. Other outcrops occur lower down the river; but it is impossible to say whether they are repetitions of the same seam or parts of this and another. Yet further down the river, near Durlipali, there is a very strong seam, over 40 feet of which was measured by Mr. Ball; it underlies the lower ironstone band, with perhaps a small intervening thickness of sandstones.

No more coal is known until the north-eastern edge of the field is reached near the deserted village of Dulunga, where, as described by Mr. Ball, strong outcrops of coal and shale occur in the river at what I take to be about the same horizon as the Durlipali seam. I also found traces of a red and purple subcuboidal concretionary ironstone, answering to the 'tessalated bed,' in close proximity to the coal outcrops, though its position above or below them is not clear. Higher up this large nala and about a couple of miles north-west, are traces of carbonaceous shale associated with the upper ironstone band.

Thence northwards, the upper ironstone beds are, as usual, easily followed on the tolerably well-defined terrace below the steep slopes of the lofty Kur and Garjan hills into the Baisandar valley, in the low grounds of which are the further coal outcrops described by Mr. Ball. These are lying, I believe, in very much the same zones of Barakars as are the other outcrops in the eastern, southern, and south-western edges of the field, though the thickness of the series may be greater.

The only remaining consideration is as to the lie or *gisement* of the rocks; and it will easily be understood, from what has been already said of their occurring so uniformly in the plateau and round its edges, that this is very easy or comparatively flat and basonal. The series has, on the whole, a general southerly slope, the lowest beds of the Barakars being at a higher level on the gneiss of the north and north-east sides of the country than they are to the southward and south-west, though the beds rise up towards this latter border and even have a sharp undulation in the escarpment of the Dibdorah valley. This easy lie has also not been interfered with by any decided system of faults;[1] but it can hardly be expected that so large an area shall be devoid of some minor dislocations, of which, however, I have as yet seen no indication.

II.—Division into Boring Areas.

In considering next the problem of selecting the most likely and convenient sites for testing the coal seams by boring, it is necessary to look at the style of the outcrops themselves, their position with regard to the line of railway, and lastly, the possibility of the line itself running over so pierceable a depth of the upper sandstones that seams may even be struck at a convenient depth within immediate reach of it.

In the first place, under these three heads, the whole field can be divided off into sections suitable either for boring or indeed for future colliery works; thus, taking them from west to east:—

I.—The Kur River Valley; practically a portion of the line trace, as the railway will enter here on its progress over the plateau from Raigarh.

II.—The Oira or Hingir River Valley; in the small Zemindari of Kodibuga, with coal outcrops.

III.—The Bagdia Valley; in the western part of Rampur, with a coal outcrop.

IV.—The Lillari Valley; in the middle of the Rampur Zemindari, and its upper reaches touching on the line of railway.

V.—The Dulunga Valley; on the north-east edge of the plateau, in Hingir, with coal outcrops.

VI.—The Baisandar and Pazar Valleys; on the north, partly in Hingir and Raigarh, with coal outcrops.

For the first, as being on the railway, I would place it as a favourable section for exploration, but that it has as yet shown no outcrops of coal. It is a convenient place, all three members of the lower Gondwanas are exposed, and there is no escarpment of the upper sandstones in the tract over which the borings would be carried out. My expectation of coal being struck here, at a depth say of 200 feet, is based on the position and strength of the coal outcrops of Dibdorah, a few miles to the south-east. On many considerations, however, it is better to start an exploration of this kind, if possible, from known outcrops such as are exhibited in all the other sections.

[1] The long faulted boundary, suggested by Mr. Ball as occurring on the south-west edge of the field, even if it be really a line of dislocation, does not affect the coal-measures in any serious way.

The Oira[1] river exhibits, without doubt, the most promising coal exposures; but these lie in an extremely narrow and shut-in valley, the escarpment being here very steep and 175 feet in height, whence it would be very troublesome to deliver the coal to the railway. On the other hand, borings might be put down on the plateau within a few miles of the railway, though these would have to be run down perhaps 200 feet before reaching coal.

The Bagdia or Lakanpur valley may for the present be left out of consideration, even though it show a coal outcrop. It forms an indented bay of low country, shut off to the north from communication with the line of rail by steep slopes of 200 feet in height, there being besides an interval of difficult country in the plateau above. The coal outcrop, as far as it shows, is not promising.

The Lillari section, as already stated, is strong in outcrops, none of which are known to contain such a thickness of actual coal as the Dibdorah exposure. This river rises in the plateau some 6 or 7 miles south-south-east of Hingir, and for part of its higher course flows close alongside the railway trace in the neighbourhood of the proposed Hingir Road Station. The northernmost or upper outcrop is only about 4 or 5 miles south-south-east of this station; while there is no difficulty of approach, the valley being quite open and without any transverse ridge or escarpment as is the case in the other parts of the field.

The Dulunga section lies about the same distance due north of this railway station; but a difficult and hilly country having more or less of an escarpment intervenes. The Baisandar and Pazar areas are even more distant and difficult of access.

My examination thus leads practically to the conclusion that the Oira and Lillari sections possess on the whole the more favourable conditions for preliminary trial. But; when comparing them as to style of outcrop, position with regard to the railway, and the possibility of striking coal at a reasonable depth, there seems little doubt that the latter offers the best combination of these attributes.

(a).—*The Lillari Valley Tract.*

The Lillari, from the neighbourhood of the Hingir Road Station to its confluence with the Ib, runs very much in a line at right angles to the rather varying strike of the rocks. Thus; in the upper part of its main course, it runs from north-north-west to south-south-east for 8 miles, when the strata are at first horizontal or nearly so, or with a dip of 5° north-north-west. Gradually, this dip may range somewhat higher as lower and lower beds of sandstone, coal, or shale are passed over, though from the fourth of these 8 miles there are strong indications of undulation. Then, as the river bends round to the eastward near Ghanamal and Durlipali, the strike of the beds is more south-west—north-east with a rather higher dip never exceeding 10°. It is thus no easy matter to estimate the probable thickness of the coal-measures, which really occupy an expanded strip of outcrop fully 5 miles in width. Calculating, however, on the varying dip and the strong indications of rolling in the middle portion, as well as on a comparison

[1] In the 4-inch map t is called the Hingir Nala in its upper reach, and the Jungwus near its confluence with the Mahanadi; but it is also marked Oira in the 1-inch topographical map and the people give it this name.

of the exposures here with those to the south-west and north-east, I do not think there can be much more than 400 feet from the top of the brown ironstone band at Chowdibahal to the bottom of the Durlipali seam.

Chowdibahal is only about 4 miles south-west of the Hingir Road Station, being situated on more or less flat beds of the Barakars, which are succeeded, as the river is followed upwards, by the red-clay band of the upper sandstones. The railway station itself will be on the middle sandstones of this series; but they are very thin, since the red-clay band rises up from under them, with a southerly dip, at only about a mile to the north-east near the village of Tangudhi.

The uppermost coal crops out in the river bed about a quarter of a mile below Chowdibahal, and the lowest also shows very strongly in the river close to the village of Durlipali. Thus the Barakars themselves can be tried by boring in two ways: either by testing the seams from below upwards beginning on the sandstones above the Durlipali seam and going north, or by starting at Chowdibahal.

The Durlipali seam is over 40 feet thick, but it is mainly made up of carbonaceous and grey shales with some thin layers of coal, the best of them being only 1′ to 2′, 6″ thick. Of course there may be a great improvement in them to the deep, but this is really all that can be said. I have, however, marked down several sites along the strike, in the sandstones above the seam, in the low hilly country on the left bank of the river, between the villages of Ghanamal (on the right bank), Judiboga (wrongly marked Jamkani on the topographical survey map), and Sumra. Should the borings at those places give good coal, the railway might then be supplied from a distance of 8 or 9 miles; they would, I think, hardly ever run beyond 200 feet, while they ought, on the Judiboga strike, to touch the coal at much lesser depths.

On the other hand, the Kuliabahal-Chowdibahal outcrop gives at least 4½ feet of fairly good coal, which may also go on improving to the deep. The slight dip would fetch the coal, if of fair lateral extent, within easy reach of the Hingir Road Station. Besides, a not unimportant feature bearing on the possible thickness and quality of this seam, or of perhaps another not far below it, must not be lost sight of, namely, that its position just below the ironstone band agrees with that of the Dibdorah and Lakanpur outcrops. It is perhaps scarcely to be hoped that these three widely separated exposures can be parts of one and the same seam; but they certainly appear to be on somewhat the same horizon which so far exhibits coal at other points also round the edge of the field.

A deep boring at this place would at once tell a great deal of the proper coal-bearing capabilities of the Barakars, as well as whether it would be worth while continuing the search here, and it might even touch the lower seam. Preferring, therefore, to depend in the commencement on such a crucial boring as this deep one promises to be, I am induced to advise breaking ground at Chowdibahal; and to this end some twelve sites have been marked in this neighbourhood within an area of about two square miles which can be taken *seriatim* according as the results shall indicate. At the same time, it is quite possible—nay, even probable—that there may be no necessity for carrying this boring to any considerable depth, as the upper seam which ought to be struck within 100 feet may be so promising that the exploration shall remain in it for some time at least.

The accompanying outline map has been prepared from that of the Topographical Survey, hill features being left out; and a few alterations have been introduced from the railway map on the same scale. The approximate positions of a few villages, not given in the topographical map, are shown and the names of others corrected. Only a few of the boring sites are here laid down.

Note on Lignite *near* Ráipur, Central Provinces, *by* PRAMATHA NATH BOSE, B. Sc. (Lond.), F.G.S., *Geological Survey of India.*

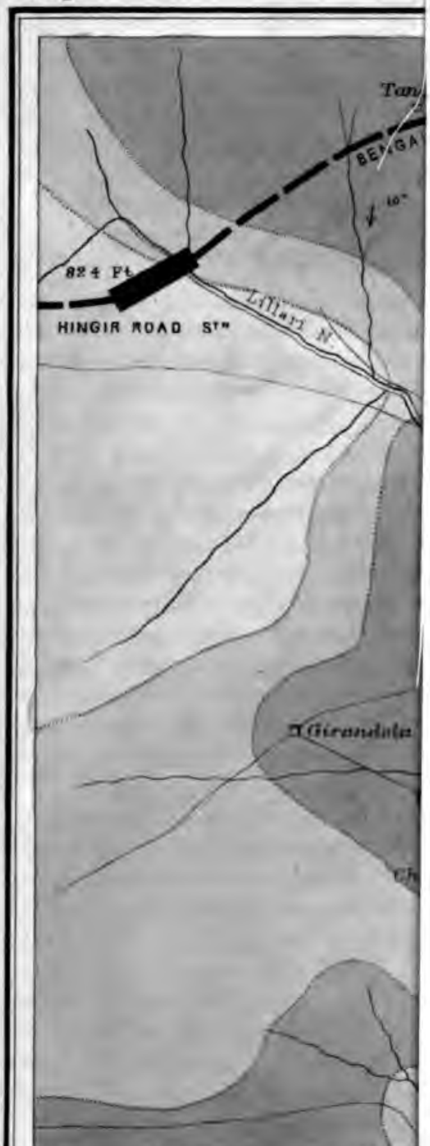
The lignite which forms the subject of this note was found in the bed of the Karun[1] river, 3 miles south-west of Ráipur, the capital of the Chhattisghar division of the Central Provinces, within the boundary of the village of Bhátágáon. When I visited the place (about the end of April) the water there was about a foot and a half deep. The bank of the river on the Bhátágáon side is some 15 feet high, and consists of a light-coloured loam. The bed is sandy; and the lignite occurs below the sand as logs in a blackish, rather stiff, alluvial clay, impregnated with peaty matter. The logs are black, and show woody structure perfectly well. Their length and thickness are variable; those I obtained had a maximum diameter of six inches. During the rains when a strong current has removed the overlying sand, these logs are, I was told, well exposed. They are then taken out by the people of Bhátágáon, stealthily it seems; for, though the villagers must have removed many cart-loads of the substance within the last ten or twelve years, and though its utility as fuel in a treeless country like Ráipur is beyond question, not a breath had reached the official ear; and Bhátágáon is only a quarter of an hour's ride from Ráipur.

From the amount reported to have been extracted by the people of Bhátágáon, and from the facility with which log after log was thrown up in my presence, I was satisfied that the lignite occurs in some quantity at the place. I cannot be very sanguine, however, considering that the alluvial deposits in which it occurs are confined to the immediate vicinity of the river and are not likely to be more than 30 feet in thickness (from the surface), if even so much, the Vindhyan limestone cropping out in all directions except the south, even in the bed of the river almost within sight of the place where the lignite occurs. On the other hand, I was informed that lignite had been found two years ago in the bed of a streamlet which marks off the boundary of the village of Khurmurá from that of Ghugwá, close to its junction with the Karun. I went to the spot. The water here was no deeper than at Bhátágáon; but my search was fruitless. From the evidence before me, however, I saw no reason to impugn the veracity of my informants. I also heard of a similar find at Jumráo, two miles and a half south of the spot where lignite was dug out at Bhátágáon. If this statement stands verification, and I think it will, the extent of the lignite would be by no means inconsiderable.

Owing to the presence of water I could not get at any exposure which would enable one to come to any conclusions worth recording about the origin of the

[1] Spelt "Karoon" in the Revenue Survey Map. The river is also known as "Kumeri."

King:



lignite, its exact mode of occurrence, and other allied questions. The specimens of lignite I got all belong to Dicotyledonous land plants, of which the jungles enclosing the plain of Chhattisghar are still almost exclusively made up. In the peaty matter associated with the lignite mentioned before were some leaves fairly enough preserved for identification. Unfortunately, those I brought away have been hopelessly crushed. When more specimens are obtained, exact specific determination would be an easy task.

The following are the results of the analyses of two specimens made by Mr. Hira Lal, of the Geological Survey :—

	No. 1.	No. 2.
Moisture	21·76	11·64
Volatile matter (exclusive of moisture)	44·84	52·36
Fixed carbon	28·30	30·00
Ash	5·10	6·00
	100·00	100·00

The excessive moisture in specimen No. 1 is probably accounted for by the fact that it was exposed to the atmosphere of the laboratory for 48 hours after it had been dried in a water bath. No. 2 was not so dried, but was sufficiently dry for analysis. The lignite was found to cake; and the ash is brownish.

The results indicate a fuel certainly poorer than coal. But the proportion of fixed carbon is higher than in ordinary peat, and the heating power consequently greater. Its economic importance cannot be exaggerated. For some 30 miles round Ráipur there is not a bit of jungle to be seen anywhere. Wood is consequently extremely dear.[1] A cheaper substitute, such as the lignite promises to be, would be highly welcome.

I came to know about the lignite in the fag end of the last season, after I had packed and stored my tents away, and made all arrangements for leaving Ráipur.[2] Next season I propose to resume work there, and have a closer search. I would recommend diggings on a small scale at Bhátágáon, Ghugwá, and Jumráo. The co-operation of an engineer will probably be required. But I have no doubt the enlightened officers of the district will cordially help in the matter.

Besides the economical importance of the subject, the scientific interest attaching to it is very great. The whole district of Ráipur has been land ever since the Vindhyan period. For ages past, therefore, it must have supported vegetable and animal life to a greater or lesser extent. But the conditions for the safe preservation of terrestrial life are so very hard, that one might hunt the whole country from one end of it to the other, without coming upon any but the barest remains belonging to the animals or the plants, which, geologically speaking, lived but yesterday. Any localities, therefore, which, like Bhátágáon, promise us materials, however scanty, for the history of the terrestrial fauna and flora, should be thoroughly and carefully searched, especially as the life-history of the entire district is a great blank, the Vindhyan sandstones and limestones having nowhere yielded a trace of a fossil yet.

[1] Firewood sells at Ráipur at 10 to 12 annas per maund.

[2] I am indebted for the information to Messrs. J. N. Sircar, Barrister-at-law, and D. Sinclair, proprietor of Bhátágáon.

The Turquoise Mines *of* Nishâpûr, Khorassan,[1] *by* A. HOUTUM SCHINDLER, *General, Persian Service.*

Geographical.—The mines known as the "Nishâpûr Turquoise Mines" are situated in the Bâr-i-Madèn, a district of the Nishâpûr province, about 40 miles north-east of Sabzvâr, and 32 miles north-west of Nishâpûr. The principal place of the Bâr-i-Madèn district is the village Madèn, which consist of two villages, the Kale-i-bâlâ and the Kale-i-paîn, with a population of about 1,200 souls. The Kale-i-bâlâ lies 5,100 feet above the level of the sea in latitude 36° 28′ 11″ north, and longitude 58° 20′ west of Greenwich. A few smaller villages, there called "kelâtehs," belong to the Madèn village, and contain about 300 inhabitants. The total population of the Madèn villages was on 1st July, 1882, 1,501. Twelve other large and several smaller villages belong to the Bâr-i-Madèn district; of these it is, however, not necessary to speak any further. The Madèn village and the territory belonging to it cover about 40 square miles of ground. Most of this is situated in a wide open valley, which, as it has no particular name, I shall call the Madèn valley. This valley, running in an east-west direction, is bounded on the north by the turquoise mountains, and on the south by the Batau mountains; on the east are some low hills separating it from the Nishâpûr plain, on the west the ground falls gently towards the Jowein plain. The thalweg of the Madèn valley is formed by the Kâl-i-Mansûrah (Kâl means river in Khorassan, or rather a river-bed), which rarely has any water, and flows nearly due west towards the Jowein plain; it reaches the Jowein plain after receiving several streams from the north, flows through the plain, and then curves southwards,

[1] Communicated; from the Foreign Department, through the Revenue and Agricultural Department, Government of India.

So little definite information concerning the occurrence of the Turquoise has hitherto been available that the above paper, even though it has but an indirect association with Indian geology, comes as a very welcome contribution to the history of precious stones. All authorities on this study give this very locality as being almost the only one whence the stone has been procured in its most perfect condition of colour; but Silesia, Oelsnitz in Saxony, and the valley of the Galasteo, south-east of Santa Fè in Europe, Thibet, and China, are given by various writers as producing stones of inferior quality. A form of very fine but not lasting colour is also found near Mount Sinai in Arabia Petræa.

In the Manual of the Geology of India, Part III, there is the following notice: "The hydrous aluminum phosphate, or calaite, otherwise known as Turquoise, may be mentioned here, though its occurrence in India is doubtful. Mr. Prinsep (Journ. As. Soc. Bengal, Vol. IV, p. 584), from the presence of certain blue streaks in the copper ores of Rajauri in Ajmir, suggested the possibility of turquoise being found there. Subsequently Dr. Irvine (Topography of Ajmir, p. 162) stated that it was reported to be found in the Ajmir hills and at Ramgarh in the Shakhwati country and was used for rings, but it seems possible that this was really a variety of blue copper which Prinsep called a turquoise copper ore. There has been no recent recorded discovery of turquoise in this region."

"The principle known turquoise mines in the world are at Ausar, near Nisâhpûr in Khorassan in Persia, to which Tavernier alluded under the name of Michobourg."

By the way, the latter name is here possibly a misprint; for Tavernier's account is thus given in Dieulafaits' "*Diamonds and Precious Stones,*" p. 141: "The mine of turquoise which furnishes the most beautiful stones is three days' journey from Meshed, turning to the north-west after passing the large town of Nishabourg."

W. K.

cutting the highroad between Shâhrûd and Meshed a little east of Abbâsâbâd. It is there passed by the Pul-i-Abrishun (Bridge of Silk), famous in former years for the Turkomans, who there, or in its immediate vicinity, attacked more caravans than anywhere else on the Meshed road.

Geological.—The mountains of the district consist of nummulitic limestones and sandstones lying on clay-slates, and inclosing immense beds of gypsum and rock-salt. The slates rise in the Batau mountain, whose peaks they form, to the absolute height of 6,400 feet, 1,860 feet above the thalweg of the Madèn valley. The limestones rise in the Sî-sar peak, 3 miles east of the Kale-i-bâlâ, to an absolute height of 5,900 feet. The stratified rocks are, on the north of the valley, broken through by porphyries and greenstones, and in consequence greatly metamorphosed, and the turquoise-bearing ridge consists entirely of porphyries, greenstones, and metamorphosed limestones and sandstones. This ridge rises to an absolute height of 6,655 feet. The turquoises form veins in the metamorphosed strata, which have partly lost their original stratification, and contain minute pieces of free silica. The general direction of the turquoise veins is N. 70° E.—S. 70° W., the same as that of the strike of the stratified rocks. The highest spot at which turquoises have been found lies 5,800 feet above the level of the sea, the lowest spot 4,800 feet.

Climate.—The climate is very salubrious. The greatest heat does not exceed 82° to 83° F., the greatest cold is very seldom 40° F. below freezing point. The winter of 1882-83 was exceptionally cold at the mines, the same as all over the north of Persia. Wheat and barley, and mulberry-trees grow well at an absolute height of 5,000 to 5,300 feet. Asafœtida and fig-trees, the latter bearing no fruit, grow on the mountain slopes to a height of 6,000 feet. The rainfall slightly exceeds that of the greater part of Khorassan. A strong north wind blows almost continually, and keeps the air very pure. Some years ago, when most of the villages of the district were ravaged by the plague, and two years ago, when there was an epidemic of diphtheria in the neighbourhood, the Madèn village remained free of sickness.

Inhabitants and produce.—The inhabitants of the Madèn village are entirely occupied with the obtaining, cutting, and selling of turquoises. Agriculture is there very much neglected. Water is not plentiful, but certainly enough for the sowing of 100 to 150 kharvars of grain; as it is, only 10 to 15 kharvars are sown, and the harvest hardly ever produces more than 100 kharvars. The villages in the immediate neighbourhood with the same kind of ground and soil, and almost the same climate, have many "deimî" fields (fields watered by rain only); the Madèn village has none. Some families occupy themselves with the rearing of silkworms, and produce about 120 lbs. of silk per annum. Poppy had been sown in a garden in 1881, but was found to contain very little opium; and the people have since then abstained from poppy cultivation. Nearly all the male inhabitants of the Madèn village are inveterate opium smokers, and many women have also acquired that vice. The gain of turquoises has made the people careless of anything else; there are, however, very few of the inhabitants who possess anything worth speaking of. A good turquoise is found, and the money obtained by its sale is spent at once; one can often see at the mines men who yearly pay 60

tomans to the Government, and who gain quite 150 tomans besides, having nothing to eat.

Mines of the district.—The mines belonging to the Madèn village are: (1) the turquoise mines; (2) a salt mine; (3) a lead mine; (4) a millstone quarry.

I shall speak separately of each.

1. *Turquoise mines.*—The turquoise mines are of two kinds: (*a*) the mines proper, shafts and galleries in the rocks; and (*b*) the Khâkî mines, diggings in the detritus of disintegrated rocks washed down towards the plain.

(*a*) The mines proper.

The most easterly, and according to all accounts the oldest mine is the Abdurrezzâgî, which was formerly called the Abû Ishâgî, and is with that name mentioned in old books. Its mouth is at the absolute height of 5,900 feet; it is a very extensive mine and has a depth of about 160 feet vertical from its mouth. For the last few years very few turquoises have been obtained from this mine, but its turquoises are esteemed more than those of other mines. Close to this mine, and in the same valley, are the Surkh, Shâperdâr and Aghâlî mines, which are at present neglected. A little to the west of the Abdurrezzâgi valley is the "Derreh-i-Safîd," the white valley, with the old mines Mâlekî, the upper and lower Zâkî and the Mîrzâ Ahmedî. The former three are immense mines, but almost entirely filled up. In the lower Zâkî, now a vertical shaft of 60 feet in depth, and about 250 feet in circumference, one can plainly see how the mines have got to their present ruined state. It is apparent that the mines were formerly well directed. Vertical shafts were cut into the rock for lighting and ventilating the mine, while the entrance of the mine was by lateral galleries driven in on the slopes of the mountains. I think it very probable that the mines were, as late as the first quarter of the last century, worked by the Government. The mines were then, when the Sefâvîeh dynasty came to an end, neglected and left to the people of the village, or perhaps, as now, farmed to them. The farmers thought only of getting a quick return for their money and cut away the rock wherever they saw any turquoises, exactly as they do at the present day. The result was that the supporting pillars and the rock between the different shafts were cut away, and that the roof, so to say, of the whole mine, fell down, filling it up. The three above-mentioned mines have been filled up like this. One can form an estimate of the original depth of the Zâkî mine from its present depth, which is only to the surface of the, formerly, superincumbent roof, and from a shaft or burrow dug into the rubbish of the old mine. This burrow begins where the fallen-down roof begins, at a depth of 60 feet from the mouth of the mine and goes down about another 60 feet vertical. At the end of this burrow, 120 feet below the mouth of the mine, there are still no signs of the original old mine. Several attempts have been made to clear this mine, but no one up to now has had either the will to provide the necessary funds or the patience to wait for the completion of the work. The turquoises of the "white valley" are also very good, not so good, however, as those of the Abdurrezzâgî. Many turquoises, generally small, are found in the rubbish of the old mines; they are much prized for their good colour. The mouth of the Mirza Ahmedî mine, which was probably once a part of the Zâkî mines, lies about 80 feet lower than that of the Zâkî

mine, and goes down 80 feet vertical. It also has very good turquoises, but working in it is very precarious on account of the bad state of the galleries and the amount of loose rubbish they contain.

The next valley is the Derreh-i-Dar-i-Kûh. In it are several important mines, the Kerbelâi Kerîmî, the Dar-i-Kûh, and others. The Dar-i-Kûh mine is very deep, going down about 150 feet vertical. It is an old and very extensive mine, and some of its galleries continue as far as the Zâkî mine; it is very dangerous on account of the rubbish it contains; the rubbish is badly propped up by stones and small sticks, and several labourers have at times been buried in it. One of its galleries called the Dânekî goes for about 100 feet through rubbish; the width of this gallery is 1 to 2 feet, its height not more, and the descent down it is very dangerous. Only three or four of the miners have the courage to go into this gallery. Some galleries of this mine are completely filled up, and can only be cleared at great expense and with difficulty. Above the mine can be seen many shafts which formerly lighted and ventilated the mine, but are now filled up. All the mines in the Dar-i-Kûh valley are worked and contain good turquoises.

Further west is the "Derreh-i-Sîyah," the black valley with the old Ali Mirzâî (a contraction of Ali Murtezâ) and the Reîsh mines. The Ali Mirzâî, particularly the lower one of that name, is very dangerous. The rock is very soft and much disintegrated, often falls and fills up the mine. A part of this mine is called the "Bî-râh-rô," the shaft "without a road"; to go down into it is very difficult. The turquoises of the Ali Mirzâî are not very good, their colour soon fades.

On the top of the Reîsh mine, in the same valley, a vein of turquoises was discovered a year or two ago, and a new mine was opened there with the name of "Sar-i-Reîsh" (the head of the Reîsh). In it are found turquoises of fine colour and of great size, but the colour soon fades and the turquoise becomes a dirty green with white and grey spots. As long as these turquoises are kept damp they preserve their colour; if once they get dry they are worth very little. A turquoise as large as a walnut and of a fine colour was found in this mine last year; it was, against my advice, or rather I was not asked, presented to His Majesty the Shah; after it had been two days with His Majesty it became green and whitish, and was found to be worth nothing.

The next valley called the "Derreh-i-Sabz," the green valley, contains the old Ardelânî and Sabz mines and the new Anjîri mines. The Ardelânî was once a very great mine; more than twelve old shafts, now all filled up, are still to be seen; its present entrance is by a large artificial cave with a dome-like roof; it has a vertical depth of 85 feet and is very badly ventilated, having several galleries with foul air. Such galleries are called "chirâgh-kush," *i.e.*, lamp extinguishers. The Ardelânî turquoises are not good. A "Jowâher nâmeh" (book on jewels), written during the seventeenth century, mentions that the turquoises of the most inferior quality were obtained from the Ardelânî.

The Sabz mine has, as its name implies, green turquoises and is at present filled up. The Anjîrî mines, which have their name from some fig-trees growing in the valley (Anjîr=fig), are new mines. They produced during the last few years a very great quantity of turquoises which had a fine colour and were sold

well. The colour of these turquoises, however, soon faded, and the possessors of these turquoises are now far from satisfied with their purchases. I believe that the great fall in the price of turquoises in Europe is mainly due to the many stones of these, as well of the Sar-i-Reîsh mines. These stones were sent to Europe and kept moist in earthenware pots till they were sold. Out of the damp they lost colour, and in a year or two they became quite white. European jewellers have at present no confidence in turquoises, and buy only at very low prices.

The next and last, also the most westerly valley, is the one with the Kemerí mine. This mine is full of water at present, and the several attempts made to empty it have failed; it has some thick veins of turquoises, but the stones are of no use for rings, being generally worked into amulets, brooches, seals, &c.

A little to the south of the Ali Mirzâî mine lies the Khurûj mine, very extensive, but partly filled up; it had, some sixty years ago, very good turquoises, and is at present not worked. There are many more mines with names, perhaps a hundred, and more than a hundred nameless ones, but they are either parts of those I have enumerated, or unimportant. Work in these mines is carried on by means of picks and crowbars, and gunpowder. Blasting with gunpowder has come in vogue only within the last thirty years; formerly all the work was done by picks, and much better: the picks extracted the turquoises entire, the gunpowder does more work, but breaks the stones into small pieces.

(*b*) The Khâkî mines are diggings in the detritus and rubbish collected at the foot of the above-mentioned mines, and in the alluvial soil, consisting of the detritus of the rocks, and extending from the foot of the mountain a mile or two down to the plain. The finest turquoises are at present found in the Khâkî mines,—in fact, good ringstones are at present obtained only from the Khâkî. Work here is carried on by promiscuous diggings, without any system whatever. The earth is brought to the surface, sifted, and searched for turquoises; the latter work is generally done by children. The fine turquoise presented by the Gavaned-Dowleh to the Shah, valued at 2,000*l.*, as well as many other fine ones, were found in the Khâkî.

2. *The salt mine.*—The salt mine is situated about 6 miles east of the Madèn village, near the little hamlet Garaghûchî. The salt consists of an immense bed of rock-salt inclosed by gypsum and nummulitic limestone. The salt is very white and clear, in many parts quite as transparent as glass. I have seen documents relating to this mine dated 1780.

3. *Lead mine.*—The lead mine lies about 6 miles south of the Madèn village in the Batau mountain (which has its name from the village Batau, lying on its southern slopes, in the Tâghûn Kûh district). The lead occurs in irregular veins, striking N. 40° E.—S. 40° W., in slates underlying limestones. The mine is not an important one, and has not been worked for many years,—in fact, not since the accession of the present Shah. As soon as the news of Muhammed Shah's demise reached Khorassan, the Amarlû Kurds revolted, and took possession of the turquoise mines. The inhabitants of the Madèn village fled to the Batau mountain, and worked the lead mine for a few months, till order was restored, and the Kurds left the turquoise mines. The mine has since then been neglected.

Millstone quarry.—The millstone quarry lies about 4 miles south of the Madèn village, on the northern slope of the Batau mountain. The stones are cut out of a rough sandstone, or quartzose grit, lying under the sandstone of the nummulitic formation. About twenty or thirty pairs of stones are obtained per annum and sold at 6 tomans a pair.

Revenue and arrangement of rent.—The Persian Government received up to 21st March, 1882, on account of these four mines, the sum of 8,000 tomans per annum. Either the inhabitants of the Madèn village paid this sum themselves, and worked the mines at their own risk, or some person farmed the mines from the Government for the same sum, retained one or two mines for his exclusive benefit, worked one or two others in partnership with some of the villagers, and sublet the remainder for 5,000 or 6,000 tomans per annum to the villagers. The villagers generally paid what had been agreed upon in turquoises, and they could sell the turquoises they obtained how and where they liked. The money which they had to pay was divided at the rate of 60 tomans "a head" among the rayots; some rayots, according to their means, number of children, &c., paying a whole head, others seven-eighths, three-fourths, &c., to one-quarter of a head, or 15 tomans a year. The Kedkhodas, of which there were five, paid nothing, and fixed the amount each rayot had to pay. Some Syeds, two or three Mullas, the barbers, and some of the relatives or friends of the Kedkhodas were also exempted. The barbers of the district possess Firmans of the Sefâvîeh monarchs, exempting them from taxes in perpetuity. I saw Firmans of Shah Tâmâsp dated A.H. 1038, of Shah Abbâs dated 1062, and of Shah Sultan Hussein dated 1091.

The salt mine was given to the Syeds of the village, in lieu of 250 tomans pension during Kerîm Khân's reign; the Syeds later sold their right to the salt mine for about 2,000 tomans to some of the villagers, who since then call the mine their private property. In the Government accounts, however, the mine still figures as Crown property, at a yearly rent of 250 tomans, and this sum is included in the 8,000 tomans which the Government receives from the turquoise mine and its villages. From the 21st March, 1882, His Majesty the Shah gave the turquoise mines, and the thereto-belonging district, to the Mukhber-ed-Dowleh for a period of fifteen years, and the Mukhber-ed-Dowleh agreed to pay 9,000 tomans the first year, and 18,000 tomans for the remaining fourteen years.

Classification of turquoises.—The turquoises are at the mines first divided in three classes or kinds: (1) Angushtarî; (2) Bârkhâneh; (3) Arabî.

1. All turquoises of good and "fast" colour and favourable shape are classed with the Angushtarî stones (ring stones). They are sold by the piece. It is impossible to fix any price or classify them according to different qualities. I have not yet seen two stones alike. A stone two-thirds of an inch in length, two-fifths of an inch in width, and about half an inch in thickness, cut "peikânî" shape, was valued at Meshed 300*l.*; another of about the same size, shape, and cut was valued at only 80*l.* Turquoises of the size of a pea are sometimes sold for 8*l.* The colour prized most is the deep blue of the sky. A small speck of a lighter colour, which only connoisseurs can distinguish, or an almost unappreciable tinge of green, decreases the value considerably. Then there is that undefinable property of a good turquoise the "zât," something like the "water" of

a diamond or the lustre of a pearl; a fine coloured turquoise without the "zât" is not worth much. A deep colour, almost an indigo-like blue, is called "talkh" bitter, and decreases the value of the stone. The best Angushtarî stones are found in the Khâkî diggings, and in the Abdurrezzâgî mine.

2. The bârkhâneh stones are generally divided into four qualities and are sold by weight. The first quality costs at the mines 1,500 to 1,600 tomans per Tabrîz mann, equal to about 90*l*. per lb. The fourth quality is worth 70 to 80 tomans per mann. Only the first and part of the second quality are sent to Europe; the others are sold in the country to Persian jewellers and goldsmiths, particularly at Meshed, and are employed for encrusting Persian articles of jewellery, amulets, dagger and sword hilts and sheaths, horse trappings, pipeheads, &c. One can at Meshed buy small cut turquoises of the third quality at the rate of 2*s*. to 3*s*. per 1,000. Many of the bârkhâneh turquoises sent to Europe are employed by the European jewellers for rings, but the mere fact of the miners themselves not classing them with the Angushtarî stones proves that they are not of the first quality.

3. *Arabî turquoises.*—All stones not belonging to the first two kinds are called Arabî. Their name is of recent origin, and was first adopted by the people at the mines for bad and in Persia unsaleable stones. Some of the miners when on a pilgrimage to Mekka had taken with them a quantity of bad turquoises and had sold them well to the Arabs. Since then any pale-coloured or greenish and spotted turquoise is called Arabî. The whitish turquoises of this kind are called shîrbûmî, or shîrfâm, and round pieces with a white crust are called chaghâleh. Many of the so-called Arabî turquoises are, however, bought by Persians, and some also go to Europe. The large flat pieces and slabs used for amulets, brooches, belt buckles, &c., at the mines called tûfâl, are now classed with the Arabî stones, although some of them are very much esteemed: pieces of 2 inches in length, 1 in width, and ⅛ in thickness, being sometimes valued at 10 tomans. Stones of a greenish colour, called Gul-i-Kâsnî (chicory) are bought principally by Afghans. I have seen about 12 lbs. in weight of pale-coloured, uncut, tûfâl stones, sold at the mines for 180 tomans.

Sale of turquoises.—About 200 men of the village work in the mines and in the Khâkî diggings, and twenty-five or thirty, the Rîsh-i-Safîds, Elders of the village, buy the turquoises and sell them to merchants and jewellers, either at Meshed or at the mines. The original finders of the turquoises do not gain much; a man who works in the mines gains on an average 5 krans per diem in turquoises. Work in the mines is difficult, but sure; a miner never returns empty-handed. In the diggings the work is comparatively easy, but the finding of a turquoise is a matter of chance. It often happens that a miner, after working hard for a few months in the mines, and having saved a few tomans, tries his chance at the diggings, works there finding nothing till his money is finished, sells and pawns his goods and chattels, still finds nothing, and finally, to keep starvation out of the doors, has to return to the mines. Good workmen never go to the Khâkî diggings, but send their children there. Of the 200 miners at the village, quite 130 work in the mines; the old and the weak, or those who possess a little property and are in no want of a certain daily gain, and the lazy, work in the Khâkî. During the summer months many strangers come to the mines

and try their chance at the diggings. The Rîsh-i-Safîds generally buy the turquoises direct from the workmen, and then sell them to the merchants at Meshed or to "dellâls" (commission agents) who visit the mines. The first profit on all turquoises is never less than 10 per cent., generally amounts to 20 per cent. That is, one of the Rîsh-i-Safîds buys turquoises for 10 tomans from a miner or from different miners and sells them to a "dellâl" for 12 tomans. The "dellâl" goes to Meshed and sells them to the dealers for 14 or 15 tomans. The dealer sorts them, sells some of them in the country and sends the remainder to Europe, generally to Moscow, where they are sold by special "dellâls" to the European dealers. It may be calculated that turquoises bought for 10 tomans at the mines are sold for 25 tomans in Europe. It is strange that European dealers have up to now not thought it worth their while to send their own agents to the mines.

The miners themselves rarely cut their turquoises, and they therefore seldom know if they have found any good stones or not. The Rîsh-i-Safîd, who is the first buyer, however, often half cuts the turquoises, and is then enabled to sort them. The Angushtarî turquoises are then put aside and sold singly, and enormous profits are often made.

The above-mentioned 300*l.* Meshed turquoise was bought from the finder by one of the Rîsh-i-Safîds for 3*l.*; the latter sold it still uncut at Meshed for 38*l.* As soon as it was cut, its true value became apparent, and it was sent to Paris, where it was valued at 600*l.* The second purchaser, however, received only 340*l.* for it; the difference was gained by the agents.

The annual output of the mines, mountains, and diggings, averaged for the last few years 25,000 tomans' worth of turquoises, valued at the mines. The final purchasers probably pay three times this amount.

Cutting turquoises, &c.—The turquoises are now generally cut by wheels made of a composition of emery and gum. The emery is brought from Badakhshân, the gum from India. The cutter drives the wheel with his right hand by means of a stick and a piece of string, which latter is twisted round the axle of the wheel; he holds the stone with his left hand against the wheel, the thumb and one finger holding the stone being protected by rags, leather, or flat pieces of wood. Wheels have not been in use long, perhaps only thirty years. Formerly all turquoises were cut on slabs of sandstone. The turquoise was held by a slit in a piece of wood, and was rapidly rubbed up and down the stone. Even now many stones are cut in this manner. Very small stones are seldom ever cut on the wheel, but always on the sandstone. After the turquoises have been cut, they are polished by being rubbed, first on a slab of very fine grained sandstone ("masgal"), and then on a piece of soft leather with turquoise dust which has been collected from the wheels. This polishing process is called "jelâ dâdan."

The pay of a turquoise cutter at the mines or at Meshed is 1 to 2 krans per diem, the cutter providing wheel and other necessaries. A cutter on stone receives never more than 1 kran per diem. The final polishing is generally done by children, who receive one-third to one-half kran per diem. One man can cut a handful of turquoises a day; one polisher suffices for three cutters. Turquoises are cut in various shapes. The shape depends on the size and original shape of the stone, as well as on its quality. The two principal shapes are the "peikânî"

and the "mussatah,"—that is, the conical and the flat. The less the cone is truncated, the more the turquoise is prized; and again a conical turquoise with an elliptical base is worth more than one with a circular base. Turquoises not possessing sufficient thickness for the "peikânî" cut, and being thicker than necessary for the flat cut, are cut *en cabochon*, and the higher the convex surface the more the value of the turquoise. Only very fine and deep-coloured turquoises are cut in the "peikânî" shape; the apex of a bad and pale-coloured turquoise would, if cut "peikânî" shape, appear almost white. The slabs of the Arabí quality are generally cut plane, seldom with a convex surface. Smaller stones are employed for seals, larger stones for amulets, &c. The larger stones are never free of flaws, and seldom have a good colour, but the jewellers very cleverly hide the flaws with a scroll-work of gold, or if there be any characters engraved on the stone, they manage to place the letters, and particularly the diacritical points, just over the flaws. I have seen sold at the mines a slab 2 inches in length for 25 krans; it had in parts a very beautiful colour, but the greater part of it was full of black spots and veins. This slab was worked up by a jeweller at Meshed, with a verse of the Gorân and some scroll-work, and sold for 60 tomans; all the spots and veins had disappeared.

Historical note.—Some of the inhabitants of the Madèn village say that their ancestors were Jews, others say that their ancestors came originally from Badakhshân, where they were ruby-cutters. Many of the inhabitants are Syeds of the family of the fifth Imâm, and one of the sons of that Imâm lies buried at the village Germâb, a few miles north-west of the mines. In a genealogical tree of one of these Syeds, written in the fourteenth century, I noticed that the name of the Madèn village was formerly Pâshân, changed later on into Fishân. The turquoise mines are rarely mentioned in Persian histories.

Salt.—The north-eastern part of Khorassan has three important salt mines: the mine near Sherîfâbâd, 24 miles south of Meshed; that of Abjû, 15 miles from Nishâpûr; and that of the turquoise mines. Meshed and its environs, and the village as far as Gadamgâh, about 16 miles to the south-east of Nishâpûr, take their salt from the first mine. Nishâpûr and its villages are provided from the second, and all the country to the north as far as Kûchân and even Askâbâd take their salt from the last mine, the one belonging to the turquoise mine village. This last mine has thus the greatest sale. It sells, at a low estimate, 15,000 loads at 150*l.* to 180*l.* each per annum, or a total quantity of about 1,100 tons. The salt is sold at the mine at the rate of 1 kran per donkey-load, which is equal to about 13 krans, say about 9*s.* per ton. The expenditure of obtaining this quantity hardly amounts to 120*l.* per annum; the salt mine, therefore, had been worked by the people who held it at a rent of 250 tomans per annum at an enormous profit. The rent was therefore increased to 600 tomans last year, and to 1,000 tomans this year.

The work at the mines, 1882-83.—I have mentioned that the Mukhber-ed-Dowleh obtained from His Majesty the Shah the concession of the turquoise mines for fifteen years, to begin from the 21st March 1882. The Shah was to receive 9,000 tomans for the first, and 18,000 tomans for each of the remaining fourteen years. The Mukhber-ed-Dowleh took in partnership Amîn-ed-Dowleh, Nassîr-ed-Dowleh, and two Tehran merchants, Hajjî Ali Nagî and Abdulbâgî,

and agreed to about three-fifths of the responsibilities, the other two-fifths being divided between the four other partners. I was sent to the mines in April 1882 as Director of the mines and Governor of the thereto-belonging district. I had orders to work all the mines, mountains and Khâkî, and monopolize the whole turquoise trade for the Company, by sending all turquoises to Tehran. I had full authority to act as I considered best for the profit of the Company regarding the working of the mines, increasing or abolishing taxes, &c. I arrived at the mines in May, and had after a fortnight organized an administration, arranged the proper working of the mines, and abolished the promiscuous sale and purchase of the turquoises by the rayots. As I worked all the mines for the benefit of the Company the rayots could in justice not be expected to pay any tax on the mines, and I reduced the 8,000 tomans they paid when in possession of all the mines to 500 tomans, which I calculated on their sheep, cattle, fields, &c. The rayots were very much satisfied with this arrangement, but difficulties soon arose. The partners, instead of letting me do as I considered best, and as really was best for them, interfered continually. Every day I received different orders; the Rîsh-i-Safîds, who under the new régime found themselves deprived of the gains they formerly had when they could buy turquoises from the mines and sell them at Meshed, intrigued; the partners of the Company neglected to supply me with money, and once when I had kept the miners seven weeks without their wages there was a strike; the villagers revolted, &c. In spite of all these difficulties I worked the mines, if not at a profit, certainly not at a loss, and left them in May of this year.

The work in 1883.—The partners then arranged to take again a tax from the villagers, 8,000 tomans instead of 5,000 as before, work a few mines themselves, and let others separately to some of the Rîsh-i-Safîds and villagers. They also continue to monopolize the turquoise trade and prohibit the selling of the turquoises by the rayots to others but their agents. They have wisely discontinued the dispatch of all turquoises to Tehran as well as the cutting of them at Tehran. They now keep only the good turquoises and sell the inferior qualities at the mines or at Meshed. The mines may with these arrangements be worked without a loss, but the profit, if there is any, is, as can be seen from the following estimate of income and expenditure, very small :—

INCOME.

Present income and expenditure.

	Tomans.[1]
Taxes on turquoise mines	8,000
„ salt mine	1,000
(These two sums are generally paid in turquoises.)	
Value of turquoises obtained from the three or four mines kept by the Company	6,000
Profit on sale of turquoises bought from the rayots, and received in lieu of taxes, 10,000 tomans bought and 9,000 tomans taxes	5,000
Total income .	20,000

[1] The present value of the toman is 6*s*. 8*d*.—Foreign Office, January 1884.

The two last items, 6,000 and 5,000 tomans, are maxima; whenever they do not reach those figures, which is very probable, there will be a loss.

EXPENDITURE.

	Tomans.
Yearly rent to Government	18,000
Administration expenses	1,500
Working expenses and wages, &c., of the mines kept by the Company	500
Total expenditure .	20,000

Tehran, October 6th, 1883.

Notice *of a further* Fiery Eruption *from the* Minbyin Mud Volcano *of* Cheduba Island, Arakán.

From COLONEL E. B. SLADEN, M.S.C., *Commissioner of Arakán, to the Superintendent, Geological Survey of India, dated Akyab, the 27th May 1884.*

I have the honour to annex for your information translation of a report by the Myoôk of Cheduba Island Township, in the Kyouk Pyu District of this Division, relative to a volcanic eruption which is said to have taken place on the island on the morning of the 28th ultimo. This is the same volcano which was in activity on the 31st December 1881, as reported in my letter under date the 4th January 1882.[1]

Report of Mra Tha Dun, *Myoôk of Cheduba Township, Kyouk Pyu District.*

The Myoôk of Cheduba respectfully begs to report that about 8 o'clock on the morning of the 28th April last the volcano in the Minbyin Circle of this Township was observed to be in eruption. The report of the eruption was brought to me by the Yazawootgoung of the place. Appended are the questions put him and his replies thereto:—

Question.	*Answer.*
1. Did the eruption burst out violently or was it gradual?	Sudden and violent.
2. To what height did the flames rise? .	Apparently about 2,400 feet (*sic*).
3. What was the circumference? . .	About 600 feet.
4. How long did the eruption last? . .	About an hour.
5. Did the flames give out any smell? .	A smell of petroleum.
6. Was there much smoke? . . .	Yes, dense smoke.
7. Was mud ejected?	Mud and gravel.

[1] See Records, Geological Survey of India, Volume XV, page 141.

Report on the Langrin Coal Field, South-West Khasia Hills, *by* TOM. D. LA TOUCHE, B.A., *Geological Survey of India*. (With a map.)

On my return from the Aka expedition in the beginning of February last, I made arrangements to visit and examine in detail the coal field situated in the Khasia Hills to the north of Langrin in Sylhet, one section in which, namely, that near Borsora, I had visited in May 1883, and described in Vol. XVI, Part 3 of the Records for that year. In that report I drew attention to the similarity between that section and the one described by Colonel Godwin-Austen as occurring on the Um Plu, a tributary of the Um Blay, about 10 miles to the north-west of Borsora (J. A. S. B., Vol. XXXVIII, Part II, No. 1, 1869), and the object I had in view was to find out whether the coal-bearing rocks were continuous in the intermediate area, and to search for other sections of the coal seams. Owing to the difficulty of procuring coolies, and my having to march across the hills from Gauhati, I did not reach the coal field till the last week in February, and so was not able to do as much as I had intended; but, as far as they go, the result of my investigations has been satisfactory. The coal-bearing rocks are exposed over an area of nearly 30 square miles, and at several points in this area, I have found exposures of coal at about the same horizon as that of the above-mentioned sections, so that there can, I think, be little doubt that there is a large amount of coal available here within a short distance of the plains.

The area examined is a plateau roughly triangular in shape, bounded on the north-east by a steep scarp overlooking the river Um Blay, on the south by the plains of Sylhet, and on the west by a range of hills of newer formation than the coal-bearing rocks. The average elevation of this plateau is about 1,500 feet above the plains, its surface sloping gradually (at an angle of 5° to 7°) to the south-west, and descending abruptly on the south to the plains. It is deeply trenched by several small streams, the two principal being the Um Plu flowing north-east into the Um Blay, and the Um Soor flowing south into the plains. Both of these have cut far back into the plateau, and flow in narrow gorges several hundred feet deep. Numerous smaller streams flow into the plains, the principal drainage being in this direction. On examination of the rocks forming the plateau, these features are found to be due to the fact that they dip to the south-west at the same angle as the general inclination of the surface until near the steep slope above the plains, where they bend over to the south at an angle of about 30°, on the line of the flexure which runs along the southern edge of the Jaintia and Khasia Hills from the Jatinga, north of Silchar, and are quickly buried beneath the alluvium of the plains. The geology of the plateau is very simple, and the succession of the rocks is well seen on ascending to it from Rilang Bazaar up the scarp overlooking the Um Blay. In the bed of the river and forming cliffs on either side of it rising to 100 feet or so in height, the lowest rock of the plateau, the Sylhet trap, is seen. This rock need not be further noticed here. Upon it rests the lower beds of the cretaceous series, about 1,000 feet of coarse felspathic sandstone, purple and blue in colour, with strings and lenticular beds of well-rolled quartz pebbles. This rock forms a steep scarp immediately over the river, and extends for about half a mile beyond the upper scarp, which rises for another 1,000 feet above it. The rocks in the

No. 1 does not cake; ash pale red.

No. 2 cakes; ash red.

With regard to the working of the coal, I would recommend that the exposures on the southern edge of the field, those nearest to the plains, should be opened out first, as the cost of carriage from the mines would be reduced to a minimum. Then, as the demand for the coal increased, the workings might be pushed further into the hills. The coal might, I think, be used with advantage in the burning of the limestone, which is quarried at the foot of the hills. At present the limestone is quarried in the cold weather, taken during the next rains to Sunamgunj on the Surma, where it has to remain till the next cold weather, during which it is burnt in a wasteful manner in holes in the river banks, the fuel used being reeds. It has then to be stored in the godowns till the rains, when it is carried to market. (Dr. Oldham, Mem. Geol. Survey, Vol. 1, Pt. II, 1858.) Two years thus elapse between the time that the stone is quarried and delivered as lime in Calcutta. Whereas if the coal on the spot were used, and kilns of the European pattern built, the limestone might be quarried and burnt during the cold weather, and the lime shipped off in the next rains, whereby a great saving in time and labour would be effected. The analyses given above show that the coal, owing to the small quantity of ash contained in it, would be excellently suited for burning lime.

Additional notes on the Umaria Coal Field (South Rewah Gondwana Basin), *by* Theodore W. H. HUGHES, A.R.S.M., C.E., F.G.S., *Geological Survey of India.*

At the close of my last year's notice of progress in connection with the Umaria coal field, I expressed the hope that another six months would furnish us with data enough to give practical answers to all practical questions. I am happy to say that the necessary stage in our investigations has been reached which enables us to do so, and I think I may now write authoritatively as to the capabilities and value of the coal deposits.

Questionable thickening of seam.

The main point shadowed in doubt was, whether the seam, which at its out-crop measured only 4 feet 2 inches to 4 feet 8 inches, increased to a more efficient thickness to the deep. The records of the borings were all in favour of the expression of most sanguine views, but unfortunately the only direct unquestionable evidence as to the behaviour of the coal rather damped the ardour of one's hopes. There was no augmentation of the seam in the inclines, though the latter had been advanced some considerable distance to the deep, and expectation had accordingly to be buoyed up by faith in the testimony of the journals handed down by Mr. Stewart in 1882.

Possible inaccuracy of journals.

There was, however, the possibility that these might have been coloured by the bias of one's proclivities, and that shales, which were nothing more than carbonaceous, had been merged in coal, and thus an excessive proportion of the latter had been registered. To those, therefore, who maintained an attitude of incredulity in the

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Alluvium. Upper Tertiar

worth of the Umaria field, this contingency and the steadiness of the seam in the inclines lent force to their views.

Test boring.

My own position was one of trust in the sections that our preliminary investigations revealed, but in order to leave no room for carping, instructions were given that a test boring should be carried out in the northern area of the field, where the seam was stated to be 10 feet thick, and that if it confirmed our previous knowledge, a shaft should be sunk, to afford facilities for examining the coal and procuring samples of it.

Superintending staff.

For the purpose of helping forward the plan of working that I had submitted to Captain Barr, the Political Agent and Superintendent of Rewah, the services of Mr. Thomas Forster, M.E., were again retained, from 1st November 1883, and with him were associated two young assistant mining engineers, M. M. Hughes-Hallett and Munsch. Their efforts were directed to completing No. 1 pit, proving Mr. Stewart's No. 9 bore hole, continuing the incline, and commencing a second shaft. Matters progressed fairly well during the first month, but great difficulty was experienced in moulding local labour, and it was deemed expedient to introduce contract work.

Contract system introduced.

After a short trial, it was found to be distinctly advantageous, and an agreement was entered into with Mr. Stoney of Katni to pay R10 per foot of sinking for the first 50 feet, and R12 for each subsequent foot up to 100. For driving in the incline R4 a ton was the rate fixed upon.

Fitters' wages.
Carpenter's wages.

Two skilled native fitters and a carpenter were imported from Karharbari to put up the necessary pit head gear and jins, and they worked very satisfactorily. They had, however, to be paid high wages, R40 and R30 a month respectively, and as soon as they could be conveniently dispensed with, they were discharged. On the western side of India, I am aware that these wages are not considered outrageous, but in Bengal men can be engaged for just one-half the sum we had to offer.

Water during sinking.

With various interruptions from causes that could not be foreseen and guarded against, each shaft was taken down to the coal. There was fortunately no difficulty in dealing with water until the seam was reached, a pair of ordinary sinking buckets being quite sufficient to keep the pits dry. We were prepared, however, for an influx when the coal was tapped, but though this fear was confirmed in the case of No. 1 shaft, strange to say in No. 2, where a much larger rush was anticipated, no body of water was met with. In one sense, the drowning of No. 1 is a favourable sign, as it implies the probability of a more extensive area of coal leading to it than had at first been surmised.

No excess of water in No. 2 shaft.

The absence of water in No. 2 is perhaps owing to one or more faults cutting off the flow in the direction of the pit. This is a mere conjecture offered in response to the natural surprise created by the phenomenal dryness of the shaft. Situated as it is in the midst of a very much larger area of coal, and much further removed as it is from the outcrop of the seam than No. 1, we certainly inferred that

there would have been a greater volume of water to cope with, but as events have proved, our apprehension was not verified. It was an extremely fortunate circumstance for us, as we were spared the necessity of indenting for expensive pumping machinery, and were enabled the sooner to bring our explorations to a decisive issue.

The boring intended to check the accuracy of the pioneer journals was put down close to Mr. Stewart's No. 9 hole, and it tallied closely with its fellow, the sections being—

No. 9 (1882). T. G. STEWART, descending.		No. 9a (1883). A. MUNSCH, descending.	
Sandstones and shales.		*Sandstones and shales.*	
(a) *Coal*	2' 0"	*Coal*	2' 0"
(b) Carbonaceous shale	1' 0"	Carbonaceous shale	3' 0"
(c) Carbonaceous shaly sandstone	3' 0"	Carbonaceous shaly sandstone	3' 0"
(d) *Coal*	10' 0"	Carbonaceous shale	1' 0"
(e) Carbonaceous shaly sandstone	3' 0"	(d) *Coal*	8' 0"
(f) Carbonaceous shale	1' 0"	Carbonaceous shale	1' 0"
(g) *Coal*	2' 0"	*Coal*	1' 0"
(h) Carbonaceous shale	1' 0"	Carbonaceous shale	1' 0"
(i) *Coal*	6' 0"	*Coal*	1' 0"
		Carbonaceous shale	3' 0"
		Coal	4' 0"
TOTAL	29' 0"	TOTAL	28' 0"

In No. 2 shaft 7' 0" clear coal.

Encouraged by the assurance of coal that these returns afforded, we[1] set out the position for the second (or No. 2) shaft, within a few yards of the bore holes; and just before the close of the season the seam at (*d*) was passed through and an open view obtained down to that level. There are 7 feet of clear coal, and all the stone interpositions that disfigure the seam in the quarry have disappeared with the exception of the clinker band. The coal is firm and homogeneous in structure, and has all the promise of being much better in quality than that cut in the incline and which was selected for the Calcutta Exhibition (1883-84).

Tender for 2,000 tons coal, G. I. P. Railway.

A considerable impetus was given to the development of the field, by the acceptance on the part of the Great Indian Peninsula Railway of a tender from the Rewah State to supply 2,000 tons of coal. The rate was R13 a ton delivered into the wagons at Katni. As neither of the shafts had reached coal, the inclines had to be extended much more than was originally intended; but with the most crude and unfinished labour and system of working, we were in a position to meet easily the demands made upon us, and we could without any anxiety have faced more onerous obligations.

Difficulty of carting coal.

The most difficult part of our contract was the carting between Umaria and Katni. We had calculated that the Government rate of 3 annas a koss for a load of 14 maunds, or R6-12 a ton, would have secured us as many carts as were requisite to

[1] Mr. Hughes was appointed Superintendent of the Rewah Coal Explorations in 1882, and has remained in charge to date.—W. K.

transfer the coal to the railway, but we found that nothing so favourable could be arranged; and we had to pay from R7-8 to R8-7 to R9-4 a ton for carriage from Umaria to Katni.

Good road between Umaria and Katni.

There is an excellent fair-weather road from one place to the other, and throughout the 20 miles that it runs in British territory, nearly all the streams are traversed by causeways. In making such excessive demands as the carters did, I presume they were reaping out of our necessities, for there could be no reasonable cause of complaint, either about the gradients or the constitution of the road. It is almost level throughout, with only one large river (the Mahanadi) to cross, and for one-third of its length it has a serviceable natural metalling of laterite and gneiss.

Coal raisings.

About 1,600 tons of coal were raised during the season. At first the output was small when there were only a few working faces, but as we headed out and more opportunity of getting at the coal presented itself, 12 to 15 tons a day was the average produce. The galleries were 6 feet high by 8 feet broad. Pillars were 20 feet. No accidents occurred to those employed in cutting, and the roof stood perfectly without any artificial support. The immunity from casualties that the men enjoyed, encouraged them to persevere in their new occupation, and we have succeeded in laying the foundation of a small mining community. I am sorry to say that no attempt was made to teach the use of the pick, either as practised by English miners, or in some modified form, though I particularly wished it; but I trust this omission will be rectified next year. Nearly 550 tons of coal were delivered to the Great Indian Peninsula Railway, and 200 tons of slack to Mr. Cook, the latter paying at the rate of R8 per 100 maunds at Umaria. Mr. Cook's object was to have fuel that he could use for lime-burning during the rains, but I have not yet heard whether it was suitable.

Running power of coal.

To test the running power of the coal on the Great Indian Peninsula Railway, Mr. Forster arranged that a trial trip should be made with a full-load train. Accordingly the local Foreman of the line, Mr. Forster, and myself left Jabalpur on the 12th of May 1884 with a baggage train of an average gross weight, excluding the engine and tender, of 410 tons that ran as far as Sohagpur (122 miles). A report of the result achieved has been submitted to the Political Agent of Rewah by Mr. Forster, and I prefer in this instance to quote approximately his words:

Mr. Forster's report.

"By the kindness of the Traffic Superintendent, Mr. Maurice, we were given a full train load of 32 vehicles. The engine supplied by Mr. Watson, of the Locomotive Department, was all that could be desired.

"We started from Jabalpur at 10-20 P.M., 12th May 1884, arriving at Sohagpur about 9 A.M. on the following morning.

"I am exceedingly glad to say that the coal steams admirably; and even when going up hill with the full load, steam was blowing off from the safety valve. The fire was cleaned out twice on the journey; not that it was really necessary, but as a precautionary measure against choking. During the trip, I noted particularly that very few sparks were thrown out, and that the coal was not more fuliginous than the general run of country coal. At starting we had 8 tons 16 cwt.

19 lbs. of coal on the tender, lighting up of engine included. The amount of coal left on tender after completing the trip was 1 ton 9 cwt. 2 qrs. 2 lbs. The consumption on the journey was therefore 2 tons 6 cwts. 1 qr. 21 lbs. The evaporation was 5·4 lbs to 1 lb. of coal."

Reducing these figures to the standard of pounds consumed per train mile, we have 8,531 lbs.—3,330 lbs.=5,201 lbs., the actual amount burnt. Then $\frac{5,201 \text{ lbs.}}{122 \text{ miles}}=42{\cdot}53$ lbs. per train mile. This is only slightly in excess of Karharbari coal, and is far less than Mohpani and Raniganj coal, the comparison being—

Karharbari.[1]	Umaria.	Raniganj.[1]	Mohpani.
40 lbs.	42 lbs.	51 lbs.	55 lbs.

The facts now established in regard to the Umaria coal field are—

1st.—That there is an abundant store of coal.

2nd.—That there is a convenient working thickness of at least 7 feet of coal.

3rd.—That the coal lies within easy access of the surface.

4th.—That the dip is slight.

5th.—That there is a good roof to the coal.

6th.—That the working power of the coal is almost equal to the Karharbari coal.

7th.—That the coal measures are not heavily watered.

Such an array of truths, and the commanding geographical position that the Umaria field holds as an area of supply for Western and North-Western India, render it unnecessary for me to enter into a lengthly advocacy of the expediency of bringing within reach of public use, *with as little delay as possible*, the splendid coal resources of the Rewah State. These can only be made available, however, by cheapening the conveyance between Umaria and Katni and substituting for the native gharrywallah a more practical form of carriage.

At present the Great Indian Peninsula Railway Company are willing to pay R13 a ton for the Umaria coal, but such a price as this would, in the interests of the coal itself, limit its area of distribution too seriously to be maintained. The aim of those who may eventually work the coal field ought certainly to be to reach as far over Central India and the North-West Provinces as possible, and one of the essential means to this end is a broad gauge railroad connecting Umaria with the most favourable point on the Jabalpur branch of the East Indian line.

It is to be hoped that no unnecessary procrastination on the part of Government will now take place in deciding what course to pursue, so that a cheap market may be thrown open to the mutual advantage of producer and consumer.

[1] Extracted from return furnished by the Consulting Engineer to the Government of India for Guaranteed Railways.

CALCUTTA;

1st July 1884.

ADDITIONS TO THE MUSEUM.

FROM 1ST APRIL TO 30TH JUNE 1884.

One sample each of pitch, tar, valveline, mineral tallow, paraffin, batching oil, lubricating oil, and burning oil, manufactured from Burmah earth oil, and a sample of Burmah earth oil.

PRESENTED BY THE 'RANGOON OIL COMPANY,' RANGOON.

Sample of a chatoyant jade, called 'cat's eye,' said to be from Central Asia.

PRESENTED BY LIEUTENANT-COLONEL SIR O. B. C. ST. JOHN, K.C.S.I., R.E.

Twenty-seven specimens of clays, glazing materials, and pigments, used in the manufacture of Indian pottery at the Bombay 'School of Art.'

PRESENTED BY B. A. GUPTE, HEAD CLERK, 'SCHOOL OF ART,' BOMBAY.

A model of the 'Gor-do-Nor' diamond, recently found in the Bellary district, Madras Presidency.

PRESENTED BY MESSRS. P. ORR AND SONS, MADRAS.

Thirty-two specimens of rocks from Dalhousie region.

PRESENTED BY COLONEL C. A. McMAHON, F.G.S., DALHOUSIE.

Specimens illustrating the malleability of sheet iron used for tin-plate making, from the 'Wilden Iron Works,' near Stourport, England.

PRESENTED BY MESSRS. E. P. & W. BALDWIN, ENGLAND.

A palæolithic implement, from surface of laterite, near Katangi, Katni tahsil, Jabalpur district: found and presented by Mrs. W. King.

ADDITIONS TO THE LIBRARY.

FROM 1ST APRIL TO 30TH JUNE 1884.

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ALBRECHT, PAUL.—Sur la fossette vermienne du crane des mammifères. 8° Pam. Bruxelles, 1884.

THE AUTHOR.

BAYLEY, THOMAS.—A pocket book for chemists, chemical manufacturers, metallurgists, dyers, distillers, brewers, sugar refiners, photographers, students, &c. 2nd edition. 12° London, 1881.

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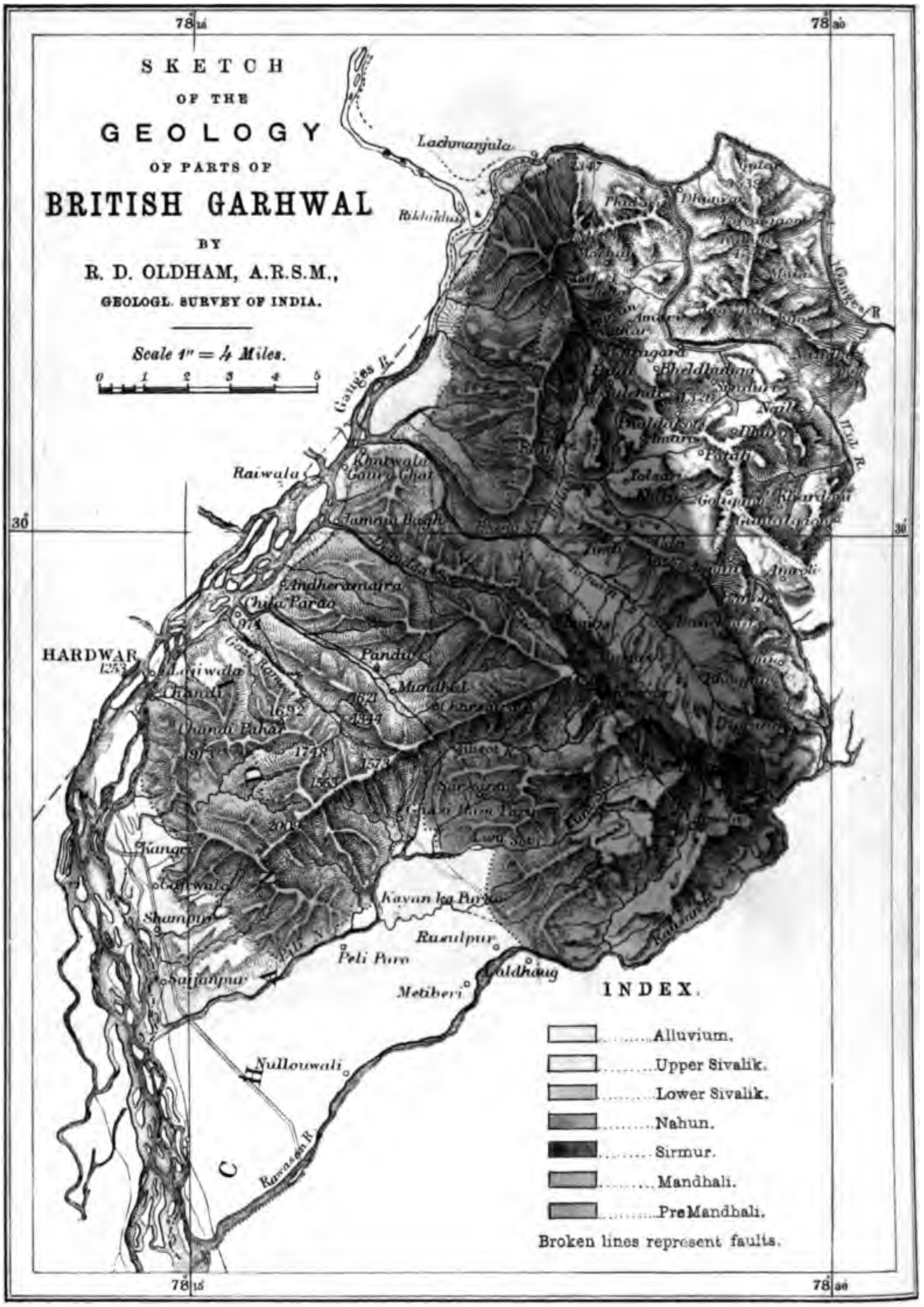


Lithographed at the Survey of India Offices, Calcutta, August 1884.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1884. [November.

Note on the Geology *of part of the* Gangasulan Pargana *of* British Garhwal, *by* R. D. OLDHAM, A.R.S.M., &c., *Geological Survey of India.* (With a map.)

1. The country to be described in this note is comprised within a strip about 5 miles broad, stretching eastwards from Rikhikhes and southwards to the foot of the Chandi hills, lies entirely to the east of the River Ganges, and presents more points of geological interest than any other Himalayan tract of equal magnitude with which I am acquainted.

Older series.

2. The oldest rocks seen I have comprehensively coloured on the map as 'Pre-Mandhâli.' With the exception of some beds of limestone exposed to the north of Latchman Jhula in the bed of the Ganges they are, to the east of the strip of Mandhulis and Sirmurs, grey schistose slates with occasional beds of quartzites, and to the west as far as the recent deposits of the Ganges black slates with quartzites and occasional calcareous beds, presenting no features of geological interest apart from the marked and sudden manner in which their strike bends round with the irregularities of the boundary of hill and plain, being northwards between the parallel of Rikhikhes and the Bheng Nadi, but bending sharply round to east and westwards immediately to the north and south of those limits; the courses of the Bedasni and Tal nadis marking the strike of the rocks they run through, while their junction is at the point where the one strike bends round to the other.

Mandhâli series.

3. The Mandhâli beds, under the name of Tal limestone, have long been known and have acquired a celebrity as the only case known of fossils being found in the pretertiary beds of the lower Himalayas; the section in the Bedasni has been already described in detail,[1] and the only addition I have to make is that an examination of the same beds in their extension along the Syair ridge shows that they lie in a synclinal and not anticlinal fold. Along the ridge they broaden out and form its high and rocky

[1] Rec. G. S. I., XIV, 100.

crest, and here limestone conglomerates of the regular Mandhâli type are seen associated with the fossiliferous beds. Near (a short way to the south of) the village of Syair the eocene beds come in to the east, the junction with the Mandhâlis being one of original contact as is marked by the occurrence of the characteristic bottom bed of the Subathu series; from here the Subathu-Mandhâli boundary runs to the north, keeping on the east of the ridge till a gap just north of Karanwas village, whence the ridge changes its character and a broad rolling summit replaces the rocky crest to the south, and here, in the gap, the ferruginous bottom bed of the Sirmurs can be seen *lapping round the eroded edges of the Mandhâli limestone.* This is a point of great interest and importance in proving that the Mandhâli series is of pretertiary age, as was inferred by me on other and more general grounds.[1] The boundary runs down about a furlong and a half from the crest of the ridge, but once more mounts on to it to the north of Bhuwan and runs away north-eastwards towards Toli. Along this part of the boundary the bottom bed is not so well seen, but as there are distinct traces of it in places, we may consider this also as a natural boundary. The great mass of the hill above Marhal is Mandhâli limestone, some of the beds fossiliferous, others conglomeratic, but many of them structureless limestone with which, as further to the south, slates and quartzites are interbedded.

Of pretertiary age.

4. To the south of the Bheng river these beds are seen on the crest of the Banas ridge extending close to, if not actually up to, the outcrop of Sirmurs, but they are not seen at its eastern extremity. Near the western boundary of the exposure there is a peculiar ferruginous breccia which seems to belong to this series, though for want of good exposures it is impossible to say whether it may not be of superficial origin.

Mandhâlis of the Banas ridge.

5. It would have been of great interest and importance as giving us a definite horizon in the Himalayan rocks, had any recognizable fossil been found in these beds; but I regret to have to say that a diligent search has met with no such reward. The shells, though all recognizable as such and well preserved, have been comminuted so as to form a sort of shell grit among which no pieces large enough to afford more than a very vague generic identification could be seen. The bed is evidently of littoral origin and this comminuted state of the shells, if preventing an accurate comparison of the horizon of the bed with European standards, was at any rate useful in readily discriminating it from the somewhat similar limestone beds of the Subathu series in which the shells were all entire or only slightly broken.

No recognizable fossils.

6. The next series seen, in ascending order, was the Subathu. Of this the exposure near Bhuwan has been described as regards its character.[2] Its western boundary has already been referred to in connection with the Mandhâli series, while the eastern is a fault; along this boundary the bottom rock is not seen and the beds immediately in contact with the grey schistose slates are somewhat high up in the series.

Subathu beds. Bhuwan outcrop.

[1] Rec. G. S. I., XVI, 197. §17.

[2] Mem. G. S. I., III, p. 88.

7. To the south of the Tal nadi there is another exposure of these beds. Of this I have only seen the eastern and western extremities, but there is no doubt that it extends continuously between the two, as within these limits all the lateral feeders of the Tal which flow from the south contain débris recognizable as derived from the Subathu series. At the eastern extremity only was the bottom bed seen, so that this strip may be faulted in.

Subathus of the Banas ridge.

8. The most northerly exposure of the sub-Himalayan beds is that opposite Rikhikhes, which has been mentioned as of Nahan age—[1] an opinion from which I find myself obliged to dissent. The exposure, whose boundaries are completely obscured by recent river gravels, consists of soft grey sandstones and sandy clays with a north by west strike and vertical dip, which, from their resemblance to the middle Sivalik beds and the entire absence in a section of some considerable thickness of any trace of the very characteristic red clays of the Nahan beds, I would refer to the former rather than the latter period. This is, however, a matter of opinion, and no definite proof can be adduced of one or the other conclusion.

Sub-Himalayan Rikhikhes.

9. The supposition advanced is, moreover, supported by the fact that the next exposure to the south, that in the Bheng nadi, contains very characteristic red clays undistinguishable from those of Nahan age in the Nahan hills. Between these two exposures the older Himalayan slates everywhere come into contact with the recent gravels, while immediately north of the Bheng a spur of the older rocks juts out a full quarter of a mile to the west of the outcrop of tertiary clays, showing that their boundary must here take a sudden bend westwards.

Bheng Nadi.

10. South of the Bheng the tertiary sandstones come into contact with the sub-recent gravels of the Ganges and continue up the Banas ridge to the gap between the two trigonometrical points marked on the 1-inch map. Between this point and the exposure in the Bheng I was unable to trace the boundary of the tertiaries. It would have been important to determine how the main boundary coming up from the south-east bends round to take in the Bheng exposure, but in the absence of definite observations I have been compelled to draw it on the map in the manner which seems best to fit in with observations elsewhere; it is, however, only conjectural, and must be taken for what it is worth. From the Bheng exposure southwards the section is on the whole an ascending one, the dip at the western extremity of the Banas ridge being to east-south-east, while the beds are soft yellowish-grey sandstones and sandy clays without a trace of red clay.

Banas ridge.

11. South of Jamnia bagh I saw no exposures till the Ghaziram Sot was entered; here soft sandstones with concretionary nodules of harder rock, and, higher up, conglomerates dip at first eastwards and westwards at low angles, settling down near the head of the stream to a steady northerly dip at about 30°. It is a noteworthy fact that both the sandstones and conglomerates contain numerous pebbles of soft tertiary sandstone.

Ghaziram Sot.

[1] Mem. G. S. I., III, 116. Rec. G. S. I., XIV, 100.

12. In the Mithi Sot, just where the old road from the Jabbar Gadh to Laldang crosses it, there is an exposure of soft pebbly sandstone, some of the pebbles being of sub-himalayan sandstone, with a vertical dip, striking to north by west. At the base of the exposure and lying east of the sandstones is a low bank of dark-red clay, possibly of Nahan age—a possibility which is rendered probable by the fact that the next exposure up stream is of compact sandstone breaking off along defined joint planes, interbedded with red nodular clays of the Nahan type having the same north by west strike. The continuation of this line of strike leads to a point on the Banas ridge, where I noticed a marked change in the nature of the débris lying on the surface of the ground, all the fragments to the west being thoroughly rounded by weathering, while those to the east generally retained some traces of the joint planes along which they had broken off and were not uncommonly sub-angular. Continued still further northwards, it would form the eastern boundary of the Bheng outcrop. These facts would seem to point to the existence of a line of fault, a consideration to which I shall subsequently return, but, whether a fault or no, it is the boundary between the Nahan beds to the east and the middle and upper Sivaliks to the west. In this same stream there are many boulders of a peculiar rock, a fine-grained micaceous sandstone undistinguishable from the Nahan sandstones but for the fact that scattered through it are sub-angular fragments of crystalline quartzite mostly 9″ to 1′ in diameter, none that I saw being larger and few much smaller. I did not see this rock *in situ*, but as the boulders of it increase in number up stream, and as they were seen above (to the east of) the line of junction, they must have been derived from the Nahan beds, notwithstanding the fact that nowhere else is so much as a pebble known from beds of undoubted Nahan age.

Mithi Sot.

13. On the eastern flank of the Chandi Hills, at about half a mile from Diowali, and just where the road from the north crosses the Khara Sot for the fourth and last time, an important section is to be seen. Here there is a long cliff of upper Sivalik sand-rock, earthy clay and shingle; to the south, soft grey pebbly sandstones come in with a dip of 30° to east by south, the actual contact not being seen. No pebbles of sandstone were found in the latter, but numerous red-clay galls, some evidently derived from clays of older date as they were laminated, the laminæ not agreeing in direction with those of the sandstone. This fact, together with their softness and the absence of beds of red clay, seems to stamp them as of middle Sivalik rather than Nahan age. The exposure terminates to the south by the slope of the hill-side passing off into the level ground, but before altogether disappearing, the hill sends out a small spur northwards into the stream; it is a small knot 10 feet long, 9 feet broad, and 6 feet high, on the up-stream side of which a hollow has been excavated in the river-bed such as is invariably found above any obstruction to the force of the current. Here a triangular surface of the sandstone beds is seen on whose eroded edges upper Sivalik conglomerates, containing many pebbles of sub-Himalayan sandstone and clay, lie with a dip of 45° to east by south. That this is not a mere case of contemporaneous erosion is proved by the facts that while the dip of the conglomerates

Diowali.

A contact section.

is 45° that of the sandstones below is only 30°, and that the boundary of the sandstone beds is not smooth and uniform, but irregular, the hard beds standing out with a sub-angular section proving that they must have been indurated, disturbed, and eroded previous to the deposition of the conglomerates above.

Chandi Hills.

14. To the south of a line running west of this the Chandi Hills are mainly composed of middle Sivalik sandstones, but are frequently capped by thin patches of the upper conglomerates, let in by local faulting or flexure, which were not mapped in detail. There seems but little doubt that it was these upper beds which yielded the fossils discovered by Dr. Falconer[1] and more recently by Mr. Lichfield in 1883.

Nature of boundary.

15. I now come to the consideration of the question whether the meridional boundary described above (para. 12) as existing between the Nahans and upper Sivaliks is to be considered as mainly due to faulting, or whether it approximately marks out the area over which the Nahans were removed by denudation previous to the deposition of the upper beds. That there was an extensive denudation of the Nahans previous to and during the deposition of the upper Sivaliks is sufficiently proved by the number of pebbles of the former to be found in the latter, but this may have been general and not largely greater near the Ganges than elsewhere, while there is no such direct proof that they were being eroded during the deposition of the middle Sivalik sandstones which are in contact with them on the Banas ridge. I saw no pebbles of sandstone in the middle Sivaliks, and if present they must be rare, but as the only pebbles to be seen are small, well rounded, and of hard quartzite, this negative evidence goes for very little. On the other hand, the straightness of the boundary, the contrast of the beds in contact, and the vertical dip, all go to prove that, even if the boundary is approximately one of original deposition, it must have been considerably modified by faulting or its practical equivalent.

Probably a fault.

16. In this connection the small exposure of Sub-Himalayan beds in the Bheng is of principal importance; their position (apart from a possible though hardly probable fault in the Bheng valley) is at the base of a section ascending to the southwards, the upper beds being of middle Sivalik age which the Bheng beds, if Nahan, as their character almost necessitates, must unconformably underlie. In this case there is a small patch of Nahans cut off entirely from the main mass to the south-east; and if we suppose that the boundary between the Nahans and the newer beds marks even approximately the area over which the former were removed previous to the deposition of the latter, we must account for the fact that the Bheng exposure has been brought up to the surface by faults, which both to the north and east have their downthrow on the side nearest to it; consequently if the Bheng outcrop is of Nahan age, the rocks to the east of the meridional fault must have been elevated and the newer beds removed by denudation, and the Nahans must originally have extended to the north of their present boundary, which must in that case be mainly due to faulting.

[1] Journ. A. S. B., VI, 233.

17. A similar issue to the last is raised by the contrast between the beds exposed at Raiwala on the west bank of the Ganges and those seen opposite them to the east. At Raiwala an exposure has been described[1] of upper Sivalik clays and conglomerates lying in an anticlinal flexure whose steeper side faces north, while to the east of the Ganges we find opposite these beds and on the same line of strike low middle Sivalik sandstones forming part of a large synclinal. Leaving the question of flexure on one side, for that at Raiwala is insignificant in size and might well lie on the flank of a much larger one, there is the difference in the horizons of the beds, those at Raiwala being high up in the upper Sivaliks, while opposite them are low middle Sivaliks if not Nahan beds—presumptive evidence of a great fault running in the bed of the Ganges with an upthrow to the east. This might, however, be explained away by the unconformity which, as I have shown above (para. 13), does exist in this region between the middle and upper Sivaliks; but, on the other hand, the continuation of this presumed fault would lead into the proved fault in the Hardwar gorge, and though this latter has a downthrow to the east, the great Bhimgoda fault, with a throw of some 15,000 feet, which almost, if not entirely, dies out against the former, would sufficiently account for any reversal of the fault to the northwards.

Boundary at Raiwala.

18. In this connection I may review the facts which show that these faults can nowhere be considered as simple dislocations, on one side of which the beds have been elevated, and on the other depressed, but that they are contemporaneous with, and have been formed *pari passu* with, the disturbance of the beds they intersect. In the Hardwar gorge, as has long been known,[2] a northerly dip of the beds to the east is confronted by a southerly dip to the west, and if, as seems probable, the lowest beds on the Chandi section are lower in the series than the beds opposite them on the Hardwar side, the fault must have an upthrow to the east hereabouts, while further north opposite Bhimgoda the upthrow is certainly to the west. In this case there must be some point in the Hardwar gorge where the throw is *nil*. Even if this supposition is incorrect, the throw of the fault must increase rapidly towards the north, and in either case we cannot consider the fault as of later date than the flexure of the beds, but must look upon it as a line of fracture, on one side of which the beds were from the first bent in one direction and on the opposite in the other.

Nature of faults.
Hardwar fault.

19. Turning now to the Bhimgoda fault, which, as I have said, does not seem to cross the Ganges at all, and if it does so only in a very modified form, we can hardly suppose it to have been of altogether posterior date to the formation of the Sivalik anticlinal, for the beds at the top of the section north of the fault are the very newest that we can call Sivalik with certainty, and had they ever been elevated and exposed to denudation must have been from their softness largely removed; it consequently becomes probable that in this case too the formation of the fault was gradual and progressed *pari passu* with the flexure of the beds it affects, rather than

Bhimgoda fault.

[1] Mem. G. S. I., III. 124.
[2] *Vide* H. B. Medlicott, Mem. G. S. I., III, 123.

that these beds were thrown into an unticlinal and the northern half then depressed.

20. This great downthrow of the Bhimgoda fault more than neutralizes the upthrow of the Hardwar fault, and consequently we find the beds facing those immediately north of the Bhimgoda fault seem to be lower in the series, arguing a northerly extension of the Hardwar fault, but with a *downthrow* to the west. Northwards the more rapid dip of the eastern beds soon extinguishes this throw until, near the Zabhar Gadh, the sudden replacement of the upper Sivaliks by middle Sivaliks seems to argue a fault coming from the east in some respects the analogue of the Bhimgoda fault. Be this so or not, to the north of this point at Raiwala the fault must have an upthrow to the east of some thousands of feet. That this complicated system of faulting is of altogether posterior date to the disturbance of the beds is impossible, and the only conclusion we can draw is that these faults must have been gradually formed contemporaneously with the disturbance, and to some extent the deposition of the beds they affect.

Northern extension of Hardwar fault.

21. To this fault in its extended sense I propose to give the name of the Ganges fault. From the mouth of the Hardwar gorge I have traced it as far as Raiwala, but to the north of this there are still indications of its existence. To it is possibly due the elevation of the pretertiary beds which has cut out the sub-Himalayan series from the Bheng northwards to Rekhikhes, and it may even extend further north into the older rocks of the lower Himalayas; but this cannot be decided except by further examination.

Ganges fault.

22. The post-pleiocene river gravels are largely developed along the western boundary of the area under description, but as they differ in no respect from those of the Dehra Dún, which I hope shortly to describe at length, it will be unnecessary to refer to them here further than to mention that they cover much of the ground which I have coloured as some older formation on the accompanying map.

Post-pleiocene.

23. Near Jamnia bagh, about quarter of a mile to the north of the camping ground, a small warm spring issues with a temperature of 73° F. on the side of a channel which has been dug to carry off the waste water from a water-mill. The water of the spring is pure and sweet, so that its temperature cannot be due to chemical action, and it is important to notice that it issues close to the line which I have indicated (para. 20) as probably a line of fault. I was informed by the natives that another warm spring had been struck near Gouree ghât a few years ago when making an irrigation cut. This latter seems to have been a failure, as a dry channel was pointed out to me whose bank had certainly been cut into at one place, but there was no warm spring. My informant reconciled this with his statement by explaining that the hole had been filled up since. On the whole the existence of this warm spring is doubtful, but it is noteworthy that the locality pointed out to me lies on the northerly extension of the Ganges fault.

Warm springs.

On fragments of slates *and* schists *imbedded in the* gneissose granite *and* granite *of the* N.-W. Himalayas, *by* COLONEL C. A. MCMAHON, F.G.S. (With a plate.)

In my paper on the Simla Himalayas (Records, X, p. 221) I recorded the following note regarding the eruptive granite of the upper Sutlej section: "Between Rárang and Jángi I found numerous blocks of mica schist caught up by and buried in the granite. They are of all shapes, and vary in diameter from 2 inches to 2 feet. These blocks are identical in appearance and composition with the mica schists through which the granite passes, and cannot, I apprehend, be due to segregative action."

Similar inclusions are to be observed in the gneissose granite at Dalhousie and its neighbourhood. In my paper on the Geology of Dalhousie,[1] I recorded the following note respecting them: "For some time I regarded these objects as concretionary in origin, but the conclusion was ultimately forced on me that they are true fragments of the adjoining schists, caught up by the granite in its passage through them. They are more numerous close to the schists than away from them; they closely resemble the schists in colour and material; and, in the Chúari section, where the porphyritic granite has been squeezed into and between the schistose beds, fragments of schists may be seen caught in the act, so to speak, of being broken off.

"Some of the included pieces—even those seen a long way from the junction of the granite and the schists—seemed to me of undoubted fragmentary origin. One, for instance, which I noticed in the Chúari section, was a long splinter 2 feet 4 inches long, and 5½ inches wide at the thickest end. In its splintery ends it seemed to give clear evidence of having been torn from its parent rock. It stood out sharply from the granite, and it was fractured transversely in several places, the cracks not penetrating into the granite."

As might be expected, on the supposition that the inclusions alluded to are really fragments of other rocks imbedded in an eruptive granite, the Jángi and Dalhousie specimens do not resemble each other at all; but, on the contrary, in most cases, are very like members of the local sedimentary strata through which the granite has penetrated.

I have now examined under the microscope thin slices of the Jángi inclusions, and of the mica schists at Jángi through which the granite has been erupted, and I have also examined specimens of the Dalhousie inclusions, and have compared them with the granite itself, and with the silurian beds found in the neighbourhood. The results are given in the following pages.

I shall, as usual, describe each slice in some detail, and then summarise the results under the head of "General Remarks" at the end.

No. 1.—Mica schist between Rogi and Pangi. A dense rock containing numerous small garnets.

No. 2.—A fine-grained dense mica schist. Pángi (Basssáhir).

M.—In No. 1 the mica is of rich Vandyke brown colour in transmitted light. The ground mass consists of quartz with a few crystals of felspar. Garnets are numerous. Parallelism of structure is not apparent in the arrangement of the mica.

[1] Rec. G. S. I., XV, p. 49.

In No. 2 the mica appears to be in part biotite and in part muscovite; the basal cleavage is well marked in both. The mica is oriented in all directions, but a general conformity to a parallelism of arrangement can be made out, and extinction is simultaneous in the great majority of leaves. Garnets are present. In the ground mass felspar predominates over the quartz. The former is in part microcline, and in part plagioclase.

In neither of the specimens did I detect a single liquid cavity with a bubble in it.

Nos. 3 and 4.—Mica schist included in granite between Rárang and Jángi.

M.—Numerous flakes of mica, the axial sections of which are a rich Vandyke brown in transmitted light, are disseminated through a quartz ground mass.

One or two crystals of muscovite are also present. The quartz contains numerous rounded microlites of mica.

I failed to detect a single liquid cavity with a bubble in this slice, though I used powers up to 400 linear.

These inclusions have evidently been subjected to great heat, but the entire absence of felspar, and of the liquid cavities with movable bubbles so characteristic of the quartz of granite, marks them off from that rock. Moreover, the character of the mica is suggestive of a schist rather than of a granite. It is in flakes, and the majority of the leaves lie in the same plane.

No. 5.—Granite between Rárang and Jángi with contained inclusion. With the aid of a pocket lens this inclusion is seen to consist of the constituents of granite in an extremely fine-grained condition. The line of demarcation between the inclusion and the granite is sharp and well defined.

M.—The examination of this specimen under the microscope confirms the result of the examination with the aid of the pocket lens. The slice contains a portion of the granite and also a portion of the inclusion. The latter contains both orthoclase and plagioclase, as well as quartz. In structure and in every particular it is a granite. The microlites seen in the slice contain shrinkage vacuoles and cracks. Flat liquid cavities with fixed bubbles are extremely abundant, whilst those with movable bubbles are not altogether wanting.

Dalhousie.

No. 6.—Inclusion in gneissose granite—Upper Mall, Bakrota. A dark, fine-grained mixture of quartz and mica, with irregular-shaped pieces of felspar here and there.

M.—The slice is composed of quartz, dark mica, muscovite, crypto-crystalline mica, garnets, magnetite or ilmenite, and ferrite.

The quartz contains gas pores and liquid cavities with movable bubbles. Microlites containing shrinkage vacuoles and liquid cavities, with movable or fixed bubbles, are numerous. One micro-prism contains liquid cavities.

The whole aspect of this slice under the microscope is that of the granite which contains the inclusion.

No. 7.—Inclusion in gneissose granite—Upper Mall, Bakrota.

M.—This slice shows the junction of the granite and the inclusion. The latter looks like an intensely altered slate, and, under the microscope its aspect is very different from the last specimen.

The inclusion is composed of quartz and biotite with some magnetite, or ilmenite, and a little crypto-crystalline mica in patches.

A small piece of felspar is entangled in crypto-crystalline mica, but it exhibits no crystalline contour. There are a few microscopic garnets. The quartz contains some liquid cavities with movable bubbles, and some of the microlites contain vacuoles. The rock has the appearance of being an intensely altered slaty rock.

No. 8.—Inclusion in gneissose granite—Upper Mall, Bakrota.

M.—This slice consists of a ground-mass of quartz in micro-grains, in which are scattered a dark mica (biotite?) in leaves, and in well-laminated crystals, small leaves and microlites of muscovite, patches of crypto-crystalline mica, garnets, and magnetite or ilmenite.

The quartz encloses liquid cavities with movable bubbles, and microlites which contain elongated vacuoles and cavities in which mineral matter has been deposited.

There is no trace of felspar.

Between Dalhousie and Chil.

No. 9.—Inclusion in gneissose granite. The hand specimen and the thin slice show the junction of the included dark slaty rock and the granite.

M.—The granitic portion of the slice contains orthoclase, microcline, plagioclase, muscovite in large leaves and in microlites, and well-laminated biotite. There are numerous intergrowths of biotite and muscovite, and crystals of the former enclose garnets.

Grains of ilmenite or magnetite are common to the granite and the slaty enclosure. The latter consists of granular quartz, a green mica, and numerous patches of micro-crystalline mica, which passes here and there into small leaves of muscovite. A few small garnets are present, but no felspar.

The quartz of the granite contains movable bubbles, but I have not detected any in the slaty inclusion.

Upper road near top of Bakrota, Dalhousie.

No. 10.—Inclusion in gneissose granite. To the unaided eye this looks like a compact rock: with a pocket lens it is seen to be sub-crystalline. It exactly resembles some rocks of the silurian series.

M.—This slice consists of an intimate mixture of very fine-grained quartz and mica. The quartz has evidently recrystallised under the influence of heat, as its minute grains exhibit a tendency to assume hexagonal outlines. The mica is of two kinds,—a green mica, and what is apparently muscovite. The former is by far the more abundant, stray leaves of muscovite only appearing here and there. There is one good-sized leaf of green mica, but the rest is in micro-flakes.

A little hæmatite and magnetite are present. There are numerous microlites, but all of them are apparently of mica.

I have not detected any liquid cavities in the quartz.

The microscopic examination of this slice leads to the conclusion that it is a fragment of slate that has been exposed to considerable heat.

No. 11.—Inclusion in gneissose granite. This specimen is so like No. 10 that a separate description is unnecessary. Both specimens under the microscope closely resemble some of the slaty rocks immediately adjoining the gneissose

granite at Dalhousie. The only difference is that in these specimens the heating has gone sufficiently far to almost obliterate the lamination. The materials are not arranged in well-defined lines, but still one has no difficulty in making out which way the grain goes.

The muscovite is not in clear leaves, as in granite, but fibres of the green mica are abundantly entangled in it.

Nos. 12-15.—A fine-grained schist included in gneissose granite. Upper Road, near top of Bakrota. In 13, 14, and 15 the hand specimens, and also the thin slice, show the junction of the granite and the schist.

M.—The granite is of the usual type, already described in previous papers under the name of gneissose granite.

The ground mass of the schist is composed of quartz in fine grains. There is no felspar. The mica varies in different slices in transmitted light, from yellow-green and brown-green, to brown. It is in large and small flakes, some of them being very minute and also in well-laminated crystals. Muscovite, crypto-crystalline mica, and schorl, are also present. There are round dots of opacite and a little magnetite.

The granite and the included schist contrast strongly with each other in the matter of liquid cavities with movable bubbles. The quartz and the schorl of the granite contain liquid cavities with large movable bubbles: the areas covered by the latter are about one-fourth of the areas of the cavities that contain them. In the schist, on the other hand, I have failed to detect any liquid cavities in any of the slices.

General Remarks.

The microscopic examination of the specimens described in this paper leads to the conclusion that, in some cases, what appear to be fragments of other rocks contained in granite are either inclusions that have been so intensely metamorphosed, and thoroughly permeated with the mineral constituents of the granite, that they have become granitic in structure and composition; or that portions of the granite itself have locally condensed into fine-grained concretionary lumps resembling true inclusions in appearance. Slices Nos. 5 and 6 are instances of such cases.

On the other hand, the microscope confirms the verdict arrived at by the unaided eye in respect of the majority of cases, and shows that what appear to be inclusions are really fragments of foreign rocks caught up and inclosed in the granite.

Three classes of true inclusions have been examined,—namely, ordinary mica schists, slaty rocks, and fine-grained silicious schists.

The inclusions found in the eruptive granite of the Sutlej valley present under the microscope the strongest likeness to the bedded mica schists through which the granite has burst.

In the case of the slaty inclusions in the Dalhousie gneissose granite, the inclusions have the closest resemblance to some local silurian fine-grained silicious rocks, and are not unlike some of the beds that occur in the stratified rocks close to the margin of the granite. They are a little more metamorphosed than the latter, but that is all. The sharp lines of lamination have been obliterated, but the direction of the grain can still be made out, under the microscope, without doubt or hesitation.

In the case of the schists, the fine foliation is still unmistakably visible to the naked eye.

One important fact about all the Dalhousie and Sutlej inclusions, except slices Nos. 5 and 6, is that the changes which have been set up in them by contact metamorphism have not led to the formation of felspar.

In nearly all my hand specimens and thin slices the junction of the granite and the inclusion is shown. The granite maintains its characteristics up to the junction, and then there is a sharp transition to the slate, or to the schist, as the case may be. In the slaty and the schistose portions of the slices felspar is absent.

Another important distinction is that though the quartz and the schorl of the granite abound in liquid cavities with movable bubbles up to the line of junction, these liquid lacunæ are absent in all the inclusions examined, except Nos. 7 and 8, No. 7 being a highly-altered rock.

These differences seem to me to be essential ones, and to be opposed to the acceptance of the segregation hypothesis as an explanation of these dark patches in the granite.

In some respects the inclusions have yielded to the metamorphosing influence of the granite, and to this influence I attribute the presence of muscovite, crypto-crystalline mica, and schorl.

A precisely similar metamorphosing influence was exercised by the granite on the adjoining stratified beds at Dalhousie; and in my paper on the miscroscopic structure of the latter (Records, XVI, p. 141), I expressed the conviction that "the crypto-crystalline mica seen in contact with the granitoid rock is due to the injection of matter from the granitic rock into the schists in a gaseous or liquid condition." I also noted that, "though the gneissose granite is rich in felspar, only one small crystal of this mineral was found in the numerous slices of rocks in contact with the gneissose granite examined under the microscope."

This complete correspondence between the slaty and schistose stratified rocks in contact with the gneissose granite, and the inclusions in the main body of the granite itself, is a strong point, I think, in the chain of evidence which leads to the conclusion that most of the sharply-outlined dark patches which occur in the Dalhousie gneissose granite are really fragments of stratified rocks caught up and imbedded in it, and that the dark patches are not concretionary nodules due to the freaks of segregative action.

Recently I have come across an inclusion at Dalhousie which, I think, sets the question completely at rest. I found it in the gneissose granite near the top of Bakrota, about half a mile from the horizon of the stratified silurian rocks.

One of my specimens has been very successfully photographed (about natural size) and reproduced as a print by the heliogravure process by Major Waterhouse in the office of the Surveyor-General to the Government of India, and forms the plate attached to this paper. Nothing could be more perfect than the proof print now before me; it reproduces the exact appearance, and almost the very colour, of a piece of the Dalhousie gneissose granite.

The inclusion represented in the plate is a section broken off from a long splinter of rock, shaped like a tent-peg, included in the granite. It is about two feet long, but I did not extract the whole of it, and cannot, consequently, say exactly how deep it penetrates into the granite. The sections, chipped off one

after the other for me by a native stone-mason, varied somewhat in size, but the three principal sides of one of these sections measured $2\frac{3}{4} \times 2\frac{1}{2} \times 2\frac{1}{8}$ inches.

The splinter of schist must have been rendered partially plastic by heat, for the fragments show that when it was entire it was somewhat crooked in the direction of its length, and the lines of foliation (see plate) are considerably bent. Thin sections of the specimen depicted in the plate are described under Nos. 12-15.

The rock is a very fine-grained schist. An examination of the plate will show how fine are the lines of foliation.

I do not think that any one, whose opinion is worth having, could examine the specimen itself, or even the plate attached to this paper, and believe that this finely foliated schist has originated in the granite itself by a process of segregation.

Had the specimen been ground down to a uniformly flat surface, the contrast between the granite and the contained fragment of schist would probably have been even greater than it is in the plate; for whilst much of the dark marking of the granite is due to superficial discoloration, the broad lines seen in the schist, on the other hand, are lines of foliation. These thin and thick lines of foliation run right through the splinter lengthways from top to bottom. The gneissose granite is perfectly granitic up to the very edge of the splinter, and in fracture and structure there is no resemblance between the former and the schistose inclusion. Moreover, as before remarked, whilst the gneissose granite is a highly felspathic rock, not a particle of felspar is present in the schist.

I cannot myself for a moment believe that segregation could produce a highly silicious, finely *foliated* schist out of a highly felspathic granite, in which porphyritic crystals are to be seen meandering about in all directions up to the very edge of the schist. If regard be also had to the long splinter-like shape of the schist, the improbability of such a result being produced by segregation is increased. One might as well believe, it seems to me, that a fossil ammonite is a product of segregation.

But perhaps some one who is disposed to assign a metamorphic origin for the gneissose granite, may affirm that the long splinter of schist is an undigested lump of the original rock from which the gneissose granite itself was formed. Should any one be found to advocate this theory, I would ask where all the felspar in the gneissose granite came from? The gneissose granite at Dalhousie, it must be remembered, is a mass over six miles in thickness that extends in an easterly and south-easterly direction for some hundreds of miles without any diminution in thickness.[1]

No felspar is found in the fragments of slate and schist embedded in the granite; and as the theory under consideration requires us to believe that these fragments were subjected to all the conditions to which the granite was subjected, the advocates of this theory will have to explain how lumps of foliated schist, or laminated slates, which were subjected to the aqueo-igneous agencies that reduced the main mass into a highly felspathic porphyritic granite, escaped being melted down and incorporated in the granite along with the rest of the sedimentary beds that supplied the material for the formation of that rock.

Is it to be believed that these lumps were subjected to all the influences that

[1] See map attached to the Manual of the Geology of India.

prevailed to produce the extreme metamorphism of the highly felspathic porphyritic granite, and yet that no felspar was formed in them?

The onus of explaining these difficulties rests on those who advance the theory under consideration, if there be any such, and until these difficulties are explained I think it would be mere waste of time to discuss this supposititious theory further.

Those who have worked, even a little, with the blowpipe, know how powerfully a moderate amount of felspar acts as a flux on quartz; and in view of this fact, it seems to me almost self-evident that the schist would have lost its fine parallel foliation, and would have been melted down and incorporated in the highly-felspathic granite, had not the latter lost much of its heat, and had it not advanced considerably towards final consolidation, before the fragment of schist found its way into it.

The past history of the inclusion cannot be the same as that of the granite. The only explanation that satisfies my mind, and harmonises all the facts, is that the felspathic gneissose granite is an intruder in the rocks where we now find it, and the unfelspathic schistose inclusions are fragments of the rocks through which the granite passed on its way to its present position.

Mr. J. Arthur Phillips, in his papers [1] on "Concretionary Patches and Fragments of other rocks contained in Granite," came to the conclusion that the inclusions contained in granites are of two distinct kinds: "Those of the first class are the result of an abnormal arrangement of the minerals constituting the granite itself, whilst those belonging to the second represent fragments of other rocks enclosed within its mass."

In the case of slices Nos. 5 and 6 (*ante*) I was long in doubt whether these inclusions represent those of Mr. Phillips' first or second class,—namely, whether they are nodules of segregation or are fragments of foreign rocks in a more advanced stage of metamorphism. But it seems to me, on further consideration, that they are more probably the latter than the former.

If it be granted that granites contain fragments of foreign rocks, it seems to me that we ought to expect to find these fragments in every stage of arrested fusion. Fragments caught up before the granite had lost very much of its heat would surely be on the verge of digestion; and if the process of assimilation were to be arrested before its completion, the fragment would approximate closely in structure and composition to the granite itself.

This hypothesis, it seems to me, accounts more naturally for most, if not for all, doubtful cases, than the theory of segregation.

Even the case put by Mr. Phillips, in his second paper, of large crystals of felspar growing out of the matrix into the inclusion, may, I think, be explained on the hypothesis above suggested. All who have studied thin slices of rocks under the microscope must be familiar with the fact that felspars and other crystals grow, as it were, by successive additions to a central core, the successive zones of growth in sanidine, hornblende, augite, and other minerals, being distinctly visible under the microscope. Dr. Sorby has shown, in the case of quartz, that the additions to a crystal, or fragment of a crystal, made at a comparatively late epoch in its history,—as for instance, to grains of quartz in a sandstone,—

[1] Quar. Journ. G. S., XXXV, p. 1; and XXXVIII, p. 216.

INCLUSION IN GNEISSOSE GRANITE

Reproduced from nature by heliogravure, Survey of India Offices, Calcutta
February 1884

GEOLOGICAL
SKETCH MAP
OF THE
TAKHT-I-SULIMAN

are often in optical continuity with the portions upon which they form. Supposing then, a felspar crystal in the matrix were in contact with the edge of an inclusion, I do not see why, in the event of the mineral matter contained in the inclusion being subjected to sufficient aqueo-igneous heat to produce molecular freedom of action, the molecules of felspar contained in the inclusion, or introduced into it from the granite, should not be attracted by crystallographic molecular polarity to the felspar in the matrix, at the edge of the inclusion, and form on it. Indeed, I think this would be very likely to happen, and the appearance of a felspar growing out of the matrix into the inclusion might be produced in this way, even in true fragments of foreign rocks imbedded in granite.

Of course, this could only happen when the foreign fragment was imbedded in granite in a highly heated condition. In the case of the long splinter of schist a fragment of which is depicted in the plate attached to this paper, it is clear that it must have been included in the granite when the latter was already partially consolidated, and had lost a considerable part of its heat.

I have found on other grounds, in my previous papers, that the gneissose granite had partially consolidated before it was intruded into the stratified rocks; and the evidence afforded by the fragment of schist under consideration confirms this conclusion. The schist would not have retained its fine foliation had the granite been in a fluid state, and at the high heat indicated by that condition.

To conclude, I think the evidence available is sufficient to show that the majority of the Dalhousie inclusions are really fragments of foreign rocks imbedded in the gneissose granite; and if so, the further inference that the gneissose granite which contains them is an eruptive rock seems irresistible.

The result of this independent investigation, therefore, is to strongly confirm the verdict on the gneissose granite arrived at on a consideration of other evidence.

Report on the Geology *of the* Takht-i-Suleman, *by* C. L. GRIESBACH, *Geological Survey of India.* (With two plates.)

Introduction.

The following notes on the geology of the group of hills of which the Takht-i-Suleman is the culminating mass, nearly due west of Dera Ismail Khan, and situated in Afghanistan, were made by me during the progress of the expedition under General Kennedy, which in November last year was undertaken for the purpose of affording a survey party under Major Holdich, R.E., an opportunity of conducting certain observations from the highest of the Takht peaks.

I was attached to this expedition officially, but, as was natural under the circumstances, opportunities for a regular geological survey were limited; had it not been that the country traversed was very barren and thus very favourable for my work, even so much could not have been done as is here presented. Although these notes and the accompanying sketch map are accordingly of a rough nature only, still I believe they give a fairly correct idea of the geological structure of this portion of the Suleman range,—a region which had never been visited by any geologist, or indeed by any European.

The expedition started on the 15th November 1883 from Dera Ismail Khan, consisting of a brigade under Brigadier-General T. G. Kennedy, C.B.; the Survey of India was represented by Major Holdich, R.E., whom I have to thank for the sketch map of the topography of the Takht region. I was attached to the expedition by order of the Government of India, to conduct the geological survey of the area.

Progress of the expedition.

The route followed by the troops after arrival at Draband was by the pass known near its entrance as the Shekh Hydur. Ascending the Zao stream, along

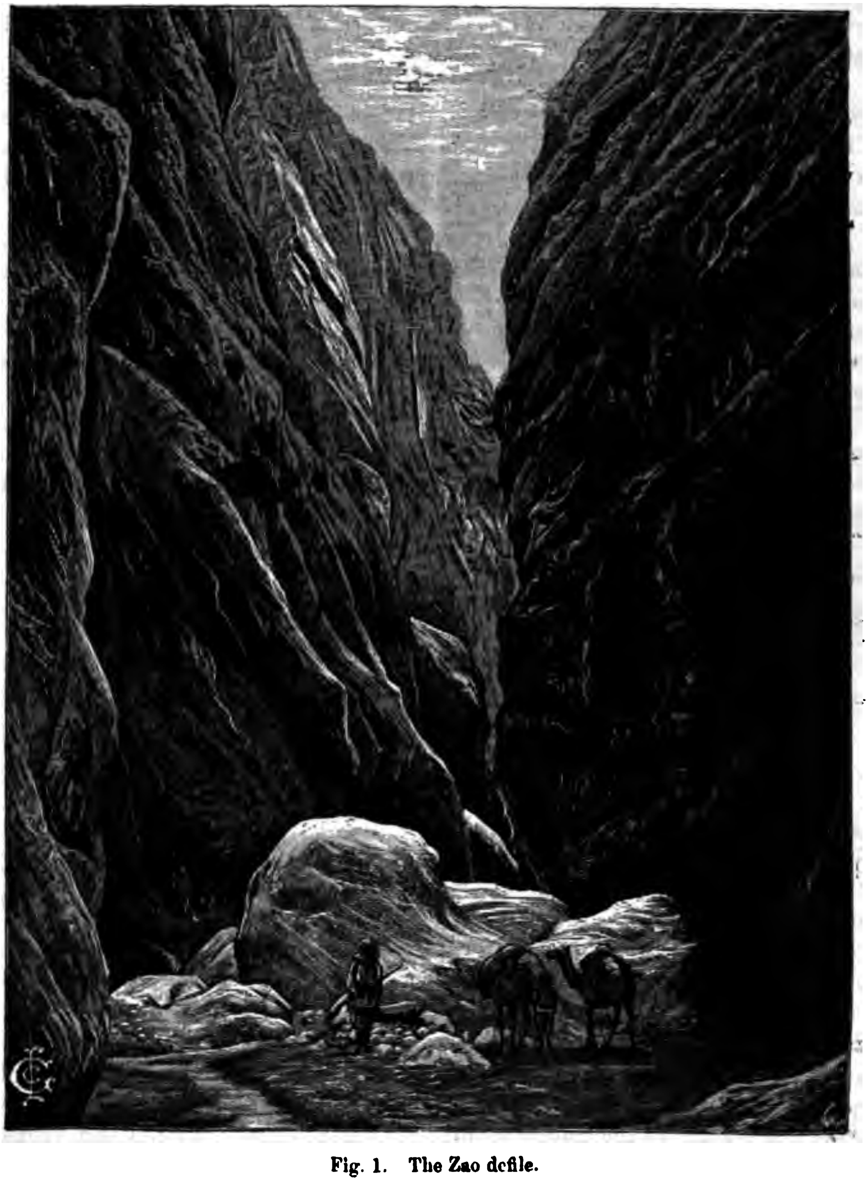


Fig. 1. The Zao defile.

its narrow defile (see fig. 1) through the main range, we eventually crossed the divide between the Zao and Draband streams, north-west of the Kaiserghar ridge, and gained the Pazai Kotal, which forms an easy ascent to the Takht "Maidan," one of the routes used by the pilgrims to the holy shrine on the top of the Takht-i-Suleman. The west-slope of the Kaiserghar ridge is greatly denuded, forming extensive undercliffs with deep ravines and precipitous and high escarpments above. The path beyond the Pazai Kotal leading up to the Maidan is along the crest of a buttress or neck left intact between two streams.

Here our expedition met with considerable resistance; one of the sections of the Sheorani tribe, the Kidderzaies, strengthened no doubt by many of the unruly "budmashes" of these hills, prepared rude defences on the rocky approaches to the "Maidan," and showed that they meant to contest our ascent. It became necessary, therefore, to take the position by force of arms, which was effectually done on the 26th November, and the road to the "Maidan" cleared. The final ascent of the highest peak of the group, the "Kaiserghar" (north peak), was effected on the 29th November by the survey party and myself, the escort being under command of Colonel MacLean, 1st Punjab Cavalry. The return march was conducted along the same route.

The very extensive and clear views which are obtained from a few of the high points (see profiles, Pl. I and II) greatly aided me in tracing out the geological structure of the region; the country is very barren, and several of the beds hereafter to be described are easily distinguished owing to their characteristic bright colours.

Previous observers.

I am writing in the field away from the resources of a library, but I believe I am not wrong in saying that we knew nothing definite relating to the "Takht" geology itself, this region never having been visited by any European. But a fair guess might have been made as several of the adjoining regions had been noticed by former travellers; and recently a sketch survey of the Suleman hills was completed up to the 30° 30′ latitude by Mr. Blanford, late of the Geological Survey of India.

Vigne, 1840.[1]
Fleming, 1853.[2]
Stewart, 1860.[3]
Verchere, 1867.[4]

None of the observers noted marginally actually traversed any portion of the area described by me. Vigne went through the Gomal pass, but his notes hardly aid in elucidating the geology of the Takht.

Fleming refers to a tract of the Suleman hills since described by Blanford.

Dr. Stewart's and also Dr. Verchere's notes have no direct bearing on the Takht region, but the first mentions the occurrence of beds near Kanigoram, slaty with thin sandstones, apparently below the nummulitic series which may possibly be of lower cretaceous age, and perhaps identical with those west of the Takht.

[1] Personal narrative of a visit to Ghazni, &c., Lond., 1840.
[2] Quar. Jour. Geol. Soc., Lond., Vol. IX, p. 346.
[3] Jour. As. Soc., Bengal, Vol. XXIX, p. 314.
[4] Ditto ditto, Vol. XXXVI, pt. 2, p. 18.

Ball, 1874.

Mr. V. Ball, then of the Geological Survey of India, was the first professional geologist who traversed the Suleman range, and has given[1] a report of the geology of the range which he crossed by the Siri Pass west of Dera Ghazi Khan.

Blanford, 1883.

The ground described by Ball has since been reported on by Mr. Blanford,[2] and I will therefore content myself with noticing a few of the remarks made by the latter, as far as they bear upon the geology of the Suleman range only; his memoir contains criticisms of my work in the Bolan and Quetta neighbourhood, some of which no doubt are just enough, but to several of his remarks I would take exception, and hope to have an early opportunity of doing so. According to his report, the physical features of the Suleman hills in latitude 30° 30′, up to which his report extends, seem much the same as those further north, where the Takht-i-Suleman forms the highest portion. The main range consisting of one or more distinct ridges is skirted eastwards by low undulating hills mostly of tertiary age which are fringed by a well marked range of siwalik rocks along the margin of the Indus plain. The following is Mr. Blanford's list of formations:—

Systems or major divisions.	Sub-divisions.	Suleman.	Geological age.
5. Recent and post-pliocene.	...	Alluvium of Indus Valley Gravels of slopes, &c.	Recent and post-pliocene.
4. Siwalik or Manchhar	Upper	1. Conglomerates 2. Sandstones and clays, &c.	Pliocene.
	Lower	Sandstones, clays, &c.	Upper Miocene.
3. Nari	Upper	Sandstones, clays, &c.	Miocene.
2. Eocene	Upper	Olive clays, shales, sandstones, &c.	Eocene.
	Lower	Coarse brown sandstone	
1. Cretaceous	...	1. Hard whitish sandstone grit	Cretaceous.
	...	2. Dark grey limestone passing downwards into limestone shales.	

It will be seen from the following pages that the main divisions and beds described by Blanford have also been identified by me in the Takht region. It will be apparent from my table on page 182 that, whilst some of Blanford's beds are wanting, there are several which seem peculiar to the Takht, unless it be that they are present in the hills west of Dera Ghazi Khan, but have not been recog-

[1] Rec. G. S. I., Vol. VII, p. 145.
[2] Mem. G. S. I., Vol. XX, pt. 2.

nised by my colleague, he never having actually crossed the high range of the Suleman hills.[1]

Physical features.

The Takht-i-Suleman is here understood to be the group of peaks, which together form a more or less square block or *massif* amongst the neighbouring ridges. It forms part of the long range known on our maps as the Suleman range, which in the area now visited has a due north and south strike (see Map). The drainage belongs to the Indus system; and the two valleys with which this report deals are those of the Zao and Draband[2] streams, both forming cross valleys through the main range, the first known as the Zao defile, and the second as the "Gut."

The general features of the ground are strikingly simple. The high region consists of two principal masses, the Takht (with the Zao[3]) hills and the Shinghar (with the Karzbina[4]) forming the axis of the range and consisting of the oldest rocks of the area.

The valleys of the Zao and the Draband rise between 3,000 and 4,000 feet above sea-level. The defile of the Draband stream (the Gut) divides the range into the Zao hills (north) and the Kaiserghar or Takht hills (south). East of this range, and skirting it, is a belt of lower ranges, much denuded by the Suleman drainage, and which, roughly speaking, form a sort of trough, of which the Suleman hills form the western and the outer hills of Siwalik rocks the eastern rim. The latter form generally the boundary between India and Afghanistan.

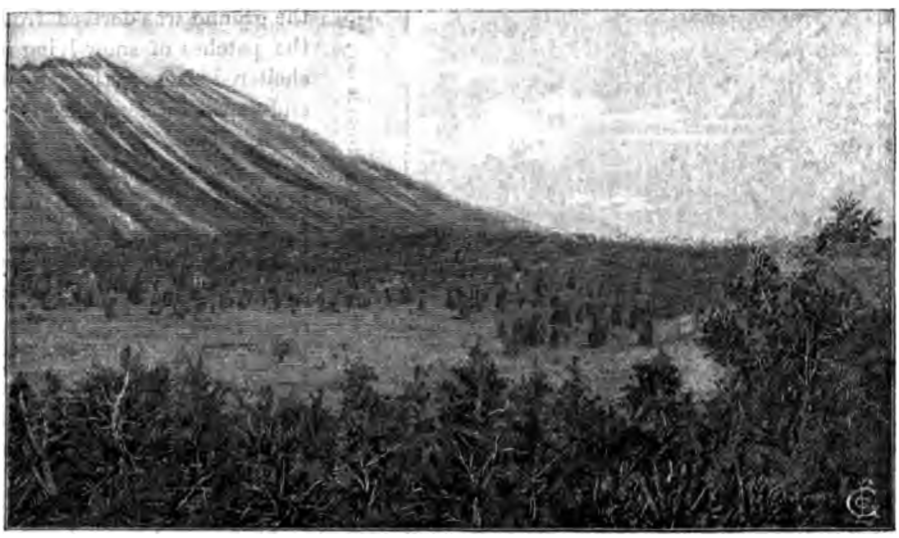


Fig. 2. View of the 'Maidan' with the Kaiserghar.

The massif of the Takht itself may be described as a high tableland (about 8,000 feet above sea-level) (fig. 2) bounded on its east and west margins by high

[1] See page 123 of his report.
[2] Major Holdich informs me that this stream is called the Lohar west of the "Gut."
[3] Zawa, Zawaghar of the map.
[4] On the map Karajbina.

rims formed by parallel ridges of rugged and steep outline. The western ridge presents the highest peak (see fig. 2) or Kaiserghar (11,300 feet), and the eastern culminates in the celebrated Takht-i-Suleman (see fig. 3) 11,070 feet.

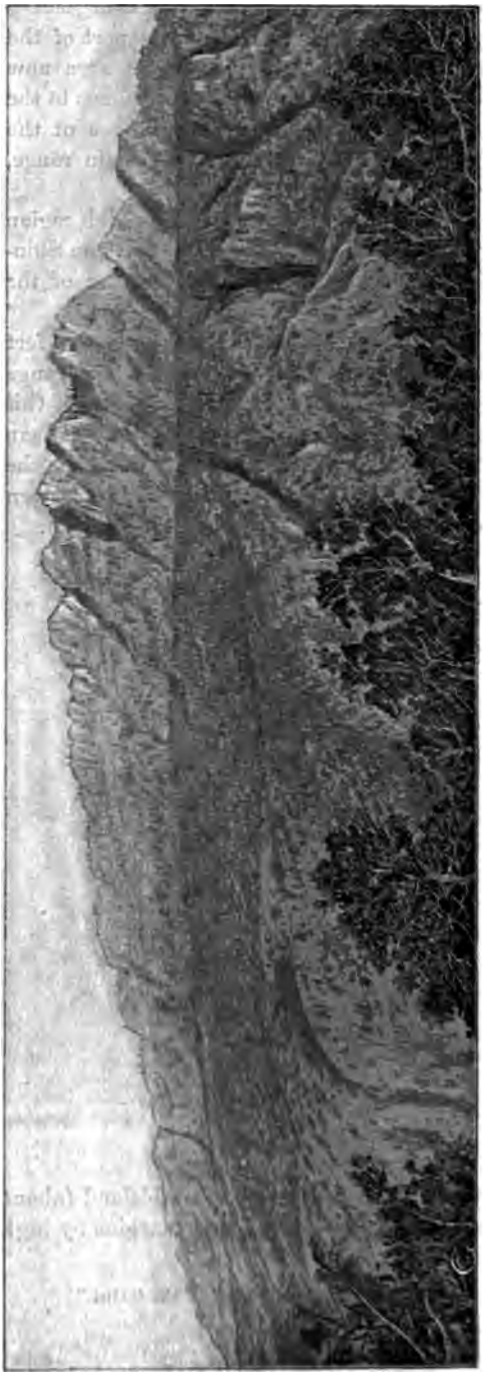


Fig. 3. The Takht-i-Suleman, Western aspect.

This tableland with its two parallel rims is altogether formed by a huge cap (if I may use the term) of coral limestone, to be presently described. The entire Maidan and part of the slopes of the bounding ranges are covered by a fine forest of the *chilkosa* or edible pine. The scenery is striking and fine, the forest-covered Maidan itself being quite park-like in its general appearance. As might have been expected, water is only found in the deep ravines during the rainy season; when we ascended the hill, the only water obtainable on the ground was derived from the patches of snow lying in sheltered places of the Maidan and on the higher slope of the Kaiserghar.

If ever this magnificent table mountain should be used for a settlement, water would have to be stored for the dry season, as has to be done in several similarly situated localities. There is now the dry basin of a naturally formed tank on the Maidan, which could of course be enlarged and deepened.

The climate is magnificent, and in November was intensely cold in the mornings.

There is (I am told) an easy road leading to the Takht from Drazand, which is usually taken by the pilgrims coming from India.

In the profile (b, Pl. I) I have given a view over the

Maidan from the top of the Kaiserghar which will illustrate the feature of the tableland with its two parallel ranges.

Geological results. I found the following formations and beds represented (see also fig. 4):—

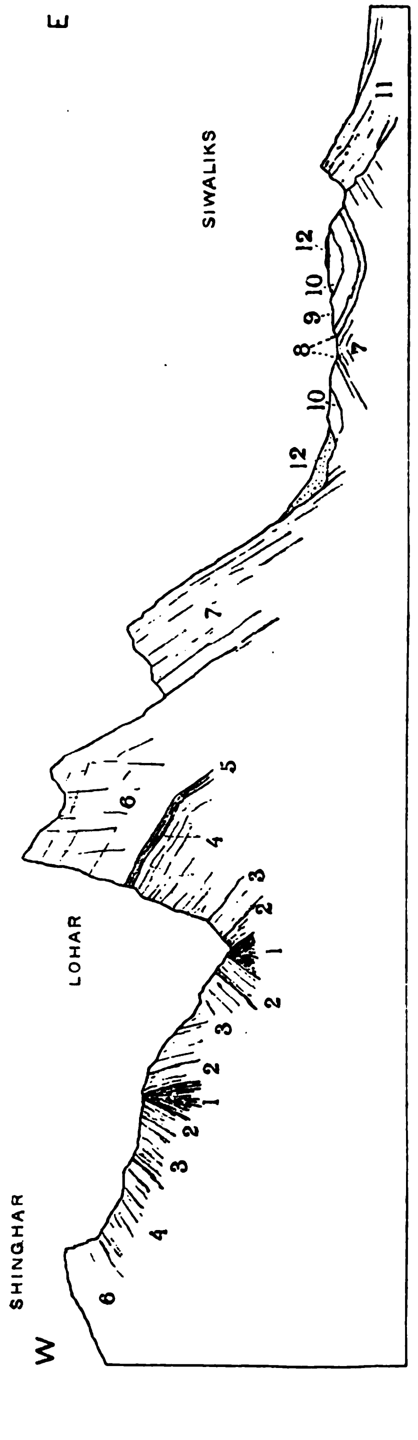


Fig. 4. Section through the Shinghar and Takht ranges to the Indus plain.

Geological age.	Sub-divisions.	Number in the section (see map).	DESCRIPTION OF ROCKS.
Recent and post-pliocene	Recent . .	12	Sands and gravels of the Indus plain.
			Gravels and fan deposits.
Pliocene . . .	Upper Siwaliks	11	Conglomerates and sandstone with clays.
Miocene . . .	Nari ? . .	10	Reddish brown to orange coloured sandstone, with bands of shales, grits, and clays; *fossils*.
Eocene . . .	Upper . .	9	Intensely bright coloured, red and olive green clays, with dividing beds of sandstone and sands; *fossils*.
	Lower .	8	Coarse brown sandstone and grits; *fossils*.
			Black carbonaceous shales (locally at Gandera Kach).
		7	White limestone; *fossils*.
Cretaceous . .	Upper . .	6	White and grey coral limestone.
	Lower .	5	Earthy shales.
		4	Hard sandstone with limestone beds.
		3	Coarse brown sandstone; *fossils*.
		2	Grey shales with calcareous irregular beds; *fossils*.
		1	Black and dark grey shales with limestone partings and concretionary nodules.

Detailed description of section.

Two distinct areas.

As mentioned before, the division of the ground into (1) the Suleman range and (2) the outer or fringing hills is striking in the extreme, and geologically the two areas are distinct; the Suleman range (where I crossed it) is formed entirely of rocks belonging to the cretaceous epoch, whereas the outer hills are all composed of tertiary and recent formations. It will be easiest therefore to begin the description of the section[1] with the main range.

1. *Suleman hills.*

Cretaceous rocks of Suleman hills.

That portion of the Suleman hills which I had the good fortune to visit, including under this name the parallel ranges of the Takht (with the Zao hills) and the Shinghar (with the Karzbina), is entirely made up, I believe, of the oldest rocks found in this part of the country. The greater mass of the range or ranges is composed of cretaceous rocks, but it is quite possible that the lowest bed of the series shown in the table and section as bed (1) is of jurassic age.

As will be seen from the figured section, the Suleman range is formed by one or perhaps more great folds of the cretaceous series. When viewed from the east, *i.e.*, the Indian side, all that seems clear is that the beds have a dip due east, passing under the tertiary beds of the outer hills. The short Zao defile, while exposing the rocks completely, affords little information as regards the structure

[1] In all cases where I refer to the "section" the ideal section is meant, fig. 4.

of the range. The rocks through which the defile cuts are greatly jointed, but it seems clear that the dip which is at first east becomes steeper, and eventually turns round to about 80° west. Near the stone in the defile, known as the Sar-i-Sang (fig. 5), the beds are raised up vertically or nearly so. Water percolating through

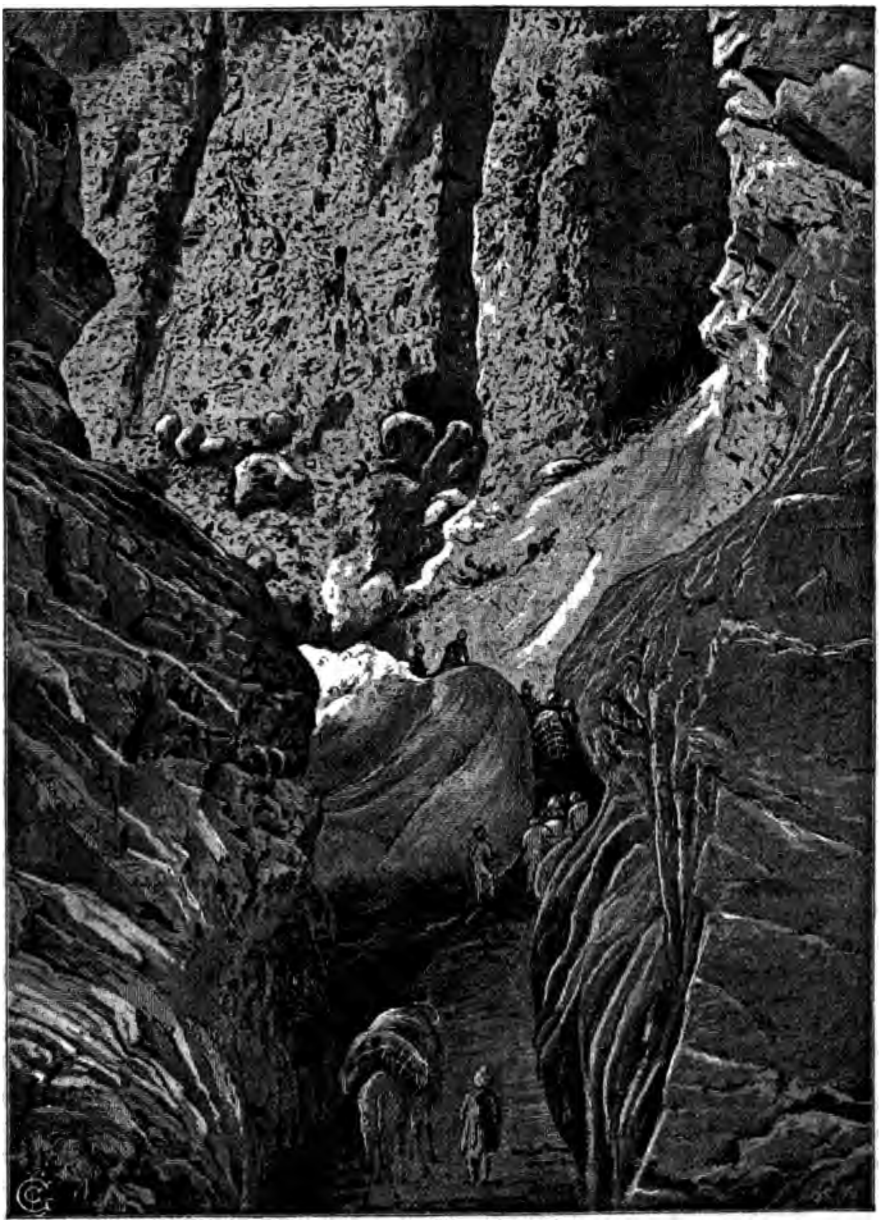


Fig. 5. The Sar-i-Sang in the Zao defile.

open joints and between the bedding has here and there removed portions of the limestone beds, leaving caves, some of them of considerable extent. At several points water issues in the form of springs out of openings between the jointed masses of the limestone beds. One of these springs in the defile has a temperature of 74° and seems to contain some mineral in solution. It is perhaps possible that the high temperature is owing to heat evolved by the decomposition of iron pyrites, common in the shaly layers between the lower cretaceous sandstones. The dip becomes uniformly west on emerging from the defile, and remains so in the Shinghar range. It was only after I had made two short excursions into the western parallel of the Suleman hills, one to the Karzbina, and another to the lower slopes of the Shinghar hills nearly opposite the Kaiserghar, that I could clearly make out the structure. This is especially well seen in the Kotal Zawasir forming the divide between the Zao and Lohar (Draband) streams, and connecting the Shinghar with the Zao range. The Kotal is shown in the profile Pl. II, near the left side of the view.

(1) Black shales.

The anticlinal which forms the Kotal Zawasir is composed of the oldest rocks seen in the area. When I say that they bear a strong resemblance to the Spiti shales of the Himalayas, most Indian geologists will recognise the character. The shales are dark grey and black, crumbling in small fragments and splinters, with a few layers of limestone and traversed by numerous calcareous veins. Here and there numbers of black concretionary nodules occur, but I have not found any fossils in them, nor in the dark shales. It is this great resemblance to the jurassic Spiti shales of the Himalayas which makes me feel doubtful concerning the cretaceous age of these shales. At all events they form the lowest beds in this range. At the Kotal Zawasir (see section and Pl. II) they form the centre of the anticlinal and are found nearly vertically raised up, dipping gradually both east and west. They may be found, more or less, along the entire west side (left bank) of the Lohar valley.

(2) Lavender-grey shales, &c.

Overlaying the dark shales, on both sides of the anticlinal axis, follow lavender grey coloured marly shales of very even texture; accompanying them are thin irregular beds of limestone, sandstone, and ferruginous shales, the exact succession and respective thicknesses I could not ascertain. But on the whole I received an impression that the grey shales were the predominant feature of this sub-division. In the ferruginous sandy shales I found some wretchedly preserved specimens of Ammonites, much crushed and in a state quite beyond specific identification. They belonged to a species with strong transverse ribs.

(3) Brown sandstones.

Next in succession above these Ammonite beds come again on both sides of the anticlinal (3 in section) brown coarse sandstones and grits with ferruginous concretionary partings; the boundaries between the sandstone and the beds below and above them are not only not defined, but the beds evidently pass gradually from one into the other. The thickness of the coarse sandstone is not great. The upper beds become gradually fine-grained, even-bedded, mostly consisting of a whitish brown or speckled quartz sandstone, with an occasional calcareous bed intercalated; towards the top of this group the limestone beds become more and more frequent,

(4) Takht-i-Suleman sandstones.

and then contain corals, which however are only seen on the worn surfaces of the limestone, being completely assimilated with the rock. A few fragments of strongly ribbed Ammonites have been found by members of the expedition, but none of them would permit specific identification.

This is probably the group also found by Mr. Blanford to compose the greater mass of the main range of the Suleman hills west of Dera Ghazi Khan. The thickness I can only guess to be not less than 800 to 1,000 feet. As will be seen in my profiles Pl. I. a, and Pl. II, and in the section fig. 4, the lower half of the western slopes of the "Takht" and the Zao ranges and also the greater part of the eastern slope of the Shinghar range are formed of this characteristic sandstone formation. In calling it such I do not wish it to be understood that it is by any means a homogeneous sandstone mass; on the contrary, towards the top especially, it becomes difficult to determine it either as sandstone or limestone, both being present. The uppermost part of this sub-division seems to contain more limestone beds than lower down.

(5) Brown earthy beds of the Kotal.

The sandstone group (4) is overlaid on the Takht-i-Suleman side of the Lohar valley by a band of perhaps 50 to 100 feet of yellowish brown earthy beds with argillaceous shales and clayey beds. I have not observed this band on the Shinghar and Karzbina side of the valley, but then the ground is less favourable for observation on that side, and I could not devote much time to that range. Seen from the opposite side (from the west) the shaly band runs in a line from just above the Pazai Kotal to above the village of Niaz Kote, south-west of the Kaiserghar (see Pl. II). The bed is of considerable economic importance, as on it apparently collects all the water found in the Takht range during the dry season, the superimposed limestone permitting all the moisture to percolate through its joints and fissures. The bed also marks a decided change in the rock formations. The streams which supplied our camp with water at the Pazai Kotal and the springs above the village of Niaz Kote all issue from this horizon.

(6) Coral limestone.

Above this lower group of sandstones and shales I found huge masses of almost unstratified coral limestone of generally a light grey colour. But dark grey masses of dolomitic character are not rare. On the whole, it reminded me of some of the coral limestones of the Quetta neighbourhood, although the latter may possibly be somewhat older.

The limestone is shown in the profiles of both plates (I and II), and in the section as (6). The appearance of this nearly unstratified mass of limestone, in which nothing but corals is observable, suggested to me the possibility of it being the remains of an ancient coral reef. This idea would receive additional confirmation by the fact that the upper coral limestone is more or less of local nature only; from Blanford's researches it would appear that the uppermost bed of the cretaceous group of the Suleman hills west of Dera Ghazi Khan is the whitish sandstone, which may correspond with bed 4 of my section; always supposing that this want is not owing to denudation.

Thickness and extent.

The thickness as seen on the Kaiserghar range may be at a rough estimate about 4,000 to 5,000 feet, if not more. It composes more than the upper half of the Kaiserghar and the Zao ranges,

and, as might have been expected, the whole of the "Takht" owes its peculiar configuration to this solid cap of limestone. It has (in the Kaiserghar range) an average dip of 20° to east. Not only the "Maidan," but also the parallel ranges of the Kaiserghar and the Takht-i-Suleman are composed of this coral limestone. The very top of the former I found of the same homogenous composition.

The bedding of it on the Takht is seen to be very little inclined to the east, but beyond it the dip quickly becomes steeper, and the coral limestone may be seen to dip under the next higher group, which as far as I could judge from my point of observation, the Kaiserghar peak, seems to rest conformably on the Takht limestone.

The crest of the Shinghar range appears also to be composed of the coral limestone (6).

The Karzbina point is composed of sandstone (4) (in fig. 5), but the crest of the range further west is evidently composed of other rock forming a high escarpment in many places. Blocks and debris of the coral limestone are also found in the ravines coming from the Shinghar range.

(7) Nummulitic limestone.

Outer hills.—Blocks of limestone, mostly rolled and containing nummulites, were found along our line of march in the Zao, below Gandera Kach. The rock had quite the concretionary appearance which is common to the nummulitic limestone of parts of the Bolan, and, as I have since found, of parts of the Salt-range.[1] It is a light grey to white dense limestone, separating into concretionary masses, which feature gives it the appearance, from a distance, of a coarse conglomerate.

I was not able to leave the road for any distance from our camp of Gandera Kach, near the entrance to the defile, and as the coral limestone of the Zao range is there quite exposed by denudation, and all the older tertiaries are removed or concealed by extensive gravel deposits, I never saw this nummulitic limestone actually *in situ*. That is to say, I have not been able to lay hands on it, for it appears to me more than probable that the much denuded and steep hills which are seen to skirt the Takht and Zao ranges on the east are composed of this rock. These skirting hills are so much a feature of the ground that they are easily recognised on the map, where as also in my profiles (Pl. I, a and b) and in my section I have marked them as nummulitics.

The tertiaries of the Zao and Draband valleys.

As has already been explained, the area lying immediately east of the Takht-i-Suleman is a belt of lower undulating hills, about 12 miles broad, greatly denuded by the Zao and Draband drainage, and bounded on its eastern margin by somewhat higher and rugged hills belonging to the upper Siwaliks. All this ground between the rugged hills marked as nummulitic limestone and the Siwalik outer hills, where not covered by recent gravel deposits, is composed of beds of limestones, clays, and sandstones with fossils, which in age range from the lower eocene to the miocene.

Time did not permit of a more detailed examination of the area, nor were the opportunities and the state of the country favourable for such work. All I could do was to separate on the map these tertiaries from the overlying

[1] As for instance north-east of Musakheyl.

siwaliks on one hand and the supposed fringing belt of nummulitic limestone on the other.

Judging from the one line along which we traversed this area, it seems probable that the rocks composing it form several folds, which are much denuded and locally obscured by large deposits of gravels. But the succession of beds, as nearly as could be ascertained, is as given in the table, page, 182 of this paper.

Doubtful horizon of certain tertiary limestones.

Below the clays and sandstones, which form the low undulating hill ground of the Zao and Draband rivers between the Takht range and the outer (Siwalik) hills, certain white and light grey bedded limestones crop up, which contrast markedly with the overlying deeply coloured clays. They are flaggy and extremely hard; search in them revealed nothing but sections of Gasteropods and some doubtful fossils. Nummulites I have not found in them, but their position below the undoubted eocene clays and sandstones of this ground, and also a certain resemblance lithologically with the nummulitic limestone boulders found there, would suggest that these bedded white limestones of the Zao belong to the uppermost portion of the nummulitic limestone (7). The sketchy nature of my reconnaisance of this valley has not permitted to distinguish these outcrops on the accompanying map of the ground.

Especially well exposed is it in the river-bed between the camping grounds marked on the map as Guldad Kach and Gandera Kach, where it forms considerable cliffs on both sides of the river. In position it is best seen just north of Guldad Kach, where the sandstone (8) and the clays (9) are seen to rest quite conformably on it. There also the unconformity between this tertiary group and the upper siwaliks is very striking.

It apparently is *in situ* in many places in the valleys formed by the Draband drainage, as can be seen from the Kaiserghar peak, from which a good view of the whole area was obtained (see b, Pl. I). It seemingly forms a low escarpment facing the east (and the siwalik hills), behind which (westward) follow the intensely coloured rocks of the upper eocene formation.

Near the entrance to the Draband valley in the fringing outer (siwalik) hills, the white limestone may be seen with its upper green and red beds dipping westwards and unconformably overlaid by the conglomerates and sandstones of the siwaliks.

Conformity.

Between this limestone (7) and the rocks marked (8), (9), and (10) in the section there is not a trace of the slightest unconformity, whereas the most marked discordance between this group and the younger siwaliks is observable. The still younger gravels and fan deposits of the Zao are of course unconformable to both the older tertiaries and the siwaliks.

(8) Sandstone, &c.

The next higher beds are formed by dark brown coarse sandstones and grits; they are present in all the outcrops of the tertiary beds in the numerous streams about Guldad Kach, and are seen to underlie the olive and red clays (9) and to rest on the white limestone (7). Apparently it contains many fossils, and a larger collection might have been made had time permitted. Nummulites, many bivalves (Pecten), and other fossils are found in great numbers.

This sandstone is easily recognised and distinguished from the sandstones found at higher horizons. The material of which the beds are made is evidently calcareous, and in places is nothing else but a breccia composed of limestone fragments and shells.

It is very probable that this horizon is identical with the sandstone (lower eocene) described by Blanford [1] from the Suleman range.

Black shales.

Locally near the camping ground of Gandera Kach in the Zao valley, I noticed a bed of black carbonaceous shale intercalated between the sandstone (8) and the white limestone (7). There are partings of shaly sandstone in these friable black shales, and there seems no definite boundary between the latter and the coarse sandstone with Pecten, &c. I have only noticed these shales at that part of the Zao valley, and it may be possible that it is a local development only. The resemblance of the black shales with the coal-bearing beds of Much in the Bolan is remarkable; I searched in consequence for coal seams, but found none. I am told by Colonel MacLean, 1st Punjab Cavalry, that coal seams are found further south in the neighbourhood of the Dana pass, but it is not known in which horizon they are found.

(9) Upper Eocene.

There is a marked contrast between the coarse sandstone beds (8) and the overlying beds. Without any appearance of gradual passage, there appear suddenly, in perfect conformity, olive green and densely Indian red clays, with only a slight indication of shaly bedding, but with partings of rusty brown sandstone. They are very rich in fossils; in fact they appear more or less made up of foraminifera, bivalves and corals. I am sorry to say that our daily marching prevented my making a good "bag" of them, but still the collection made will assist in defining their exact horizon when compared.

I have little hesitation in identifying this clay group with the olive green clays of the upper eocene of the Suleman hills, described by Blanford.

The olive green and red clays occupy nearly all the slopes of the low hills forming the country immediately east of the Takht range. Being soft and easily carried away by the rains, they are greatly denuded and traversed by deep ravines in every direction. They are overlaid by the harder beds of the next succeeding horizon, and consequently the usual effect of denudation is visible; the clays and sands of the upper eocene are gradually removed by denudation and disintegration, whilst the more resisting sandstones of the higher beds slip after them. The undercliff is therefore generally made up of blocks and slipped masses of the higher beds, whilst the latter form steep escarpments above the bright coloured clays (9).

From the high point Karzbina (see profile a, Pl. I), I obtained a good view of some of the country forming the lower Zhob and Gomal valleys. As far as I can form an opinion from such a distance, the tertiary beds and amongst them the bright coloured clays of the eocene series are largely represented in these valleys; at least bands resembling those seen in the lower Zao are seen to take part in the formation of the hills on the lower Zhob and Upper Gomal. Some high hills south-west of the latter also seem to belong to the tertiary group. A visit to this ground by a geologist ought to be extremely interesting.

[1] Mem., G. S. I., Vol. XX, Pt. 2, p. 85.

Conformably resting on the bright coloured strata (9) of the upper eocene, I met a group of rocks, mostly sandstones of a bright reddish brown, weathering orange coloured, with subordinate beds of sandy shales and clays. Some beds become locally grits and here and there are almost conglomeratic. They are well seen in the nearly flat-topped hills north-west of Guldad Kach, where they form steep escarpments above the upper eocene. In places they contain many fossils, mostly foraminifera and corals, but none in very favourable condition.

(10) Miocene beds.

I believe I may safely identify these beds with Blanford's Nari beds of the Suleman range, which he considers to be of miocene age.

All these beds are of marine origin and are continuous in succession, not a trace of unconformity being traceable throughout, from the lower cretaceous of the Lohar valley to the miocene sandstones of Guldad Kach.

Siwaliks.

The tertiary beds of the Zao and Draband valleys are seen to be overlaid unconformably by two distinct formations of gravels, conglomerates, sands, and sandstones.

The older formation of these two occurs, so far as I have observed, only in a more or less narrow belt, just fringing the marine tertiary zone east of the Takht, where it forms a high rim as it were or wall of broken and jagged outline. So far as outward physical appearance goes, there is no difficulty whatever in at once identifying this fringing belt of hills with the Manchhars or Siwaliks of Biluchistan, which I have seen myself, and no doubt they are a continuation of the siwaliks of the hills west of Dera Ghazi Khan as described by Blanford.

The beds composing these hills of siwalik rocks all dip to the east and are seen along the whole line of boundary to rest perfectly unconformably on and almost at right angles with the marine tertiary beds below. This feature is especially well seen west of the gorge which the Zao stream has cut through these rocks, which is called the Shekh Hydur Pass, and may also plainly be observed in a similar position, near the Draband stream gorge, in these rocks a few miles south of the Shekh Hydur Pass.

Only Upper Siwaliks represented.

Apparently only the upper beds of the Manchhars or Siwaliks are represented in the sections east of the Takht, and of them only a small thickness (comparatively) is exposed. With the exception of irregular and thick beds of a coarse brown sandstone, with gritty portions and a few clay beds, the whole group seems to be made up of coarse conglomerates of eocene and cretaceous limestones, cemented together by a sandy matrix. Fossils I have none out of it. Towards the Draband valley the zone seems to dwindle in width, the dip increasing and the beds disappearing beneath the alluvium of the Indus plain of Draband.

Fan deposits.

Distinct from the conglomerates of the outer or siwalik zone are the very extensive deposits of gravels and sands, which I found to rest more or less horizontally on the marine beds of the Zao valley. To distinguish these extensive deposits on the map was quite impossible, as the outlines of the overlying patches are doubtless very complicated and would require a closer examination than I could have devoted to this hostile district. In general appearance they resemble the upper siwaliks as seen in the

fringing belt; as far as I could form an opinion, angular fragments of rocks, some of very large size, are common in the gravels and conglomerates of the fan deposits. Portions of the siwalik hills near the Shekh Hydur Pass are also overlaid unconformably by the more recent gravels, so that I believe myself to be right in separating them altogether from the former, as also from the recent alluvial beds of the Indus drainage.

The gravels of the "fans" increase in thickness as we near the main range of the Takht, and where cut through by the streams (such as the Zao) the thickness of the gravel deposits is seen to be some 500 or 600 feet. Towards the siwalik belt the thickness is reduced to a few feet.

I believe the recent gravels belong to one or more huge fan deposits of an older drainage of the Suleman hills. As the denudation went on in the softer rocks of the tertiary, no doubt new channels were cut and much of the fans again removed, and the gorges of the siwalik outer hills formed, leaving patches of the younger gravels high above the level of the present streams.

Indus alluvium.

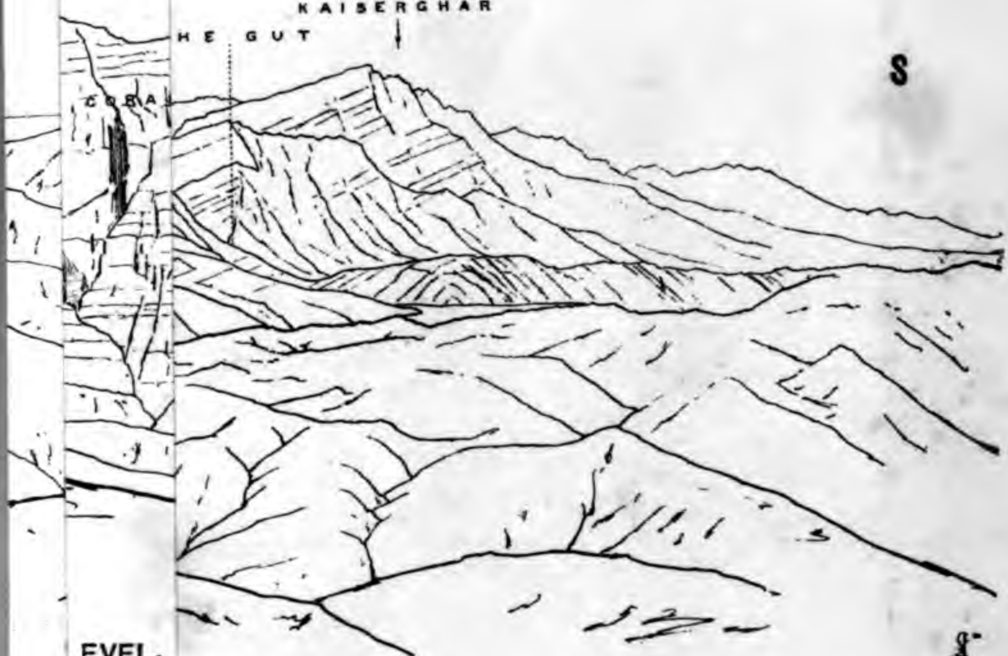
Distinct from the fan deposits are the alluvial beds of the present streams, such as the boulder and gravel deposits and sands of the Zao and Draband streams and the fine silt and clayey sands of the Indus valley east of the hills of upper siwalik age.

To this most recent formation of debris of course belong the taluses of the various ranges and the huge boulders which have caused so much trouble to the caravans passing through the narrow defiles of the Suleman range, such as, for instance, the Zao defile. In some parts this defile seems filled with a confused mass of strange shaped limestone boulders, and at least one is a well known, and I might almost say, historic boulder, *i.e.*, the Sar-i-Sang (see fig. 5). Others are denuded by the streams into strange shapes, such, for instance, as is shown in the view, fig. 1.

Their origin is simple enough; most of them belong to the dense grey coral limestone of the upper cretaceous group; the entire mass of which appears to be greatly jointed and separated into large solid masses. The sides of the defile are almost vertical and therefore very little of the disintegration which must always take place would suffice to send huge intact blocks down the precipitous sides to be afterwards worn into various shapes by the tremendous rush of water which fills the defiles during the rainy seasons. The Sar-i-Sang has fallen into one of the narrowest parts of the defile, where it has jammed itself fast. The river flowing round it has denuded it into a more or less round shape, whilst gradually its base became enveloped in silt and gravels.

Note on the Smooth-water Anchorages *of the* Travancore coast, *by* R. D. OLDHAM, A.R.S.M., *Geological Survey of India.*

On the Travancore coast there are certain spots where, in the height of the south-west monsoon, and on a coast exposed to its full force, ships can always anchor in smooth water. These anchorages have long been known to mariners, and have at various times attracted attention. In 1881 they were visited by Dr. W. King, Deputy Superintendent of the Geological Survey of India, who



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PHOTOZINCOGRAPHED AT THE SURVEY OF INDIA OFFICES, CALCUTTA, MARCH 1884.

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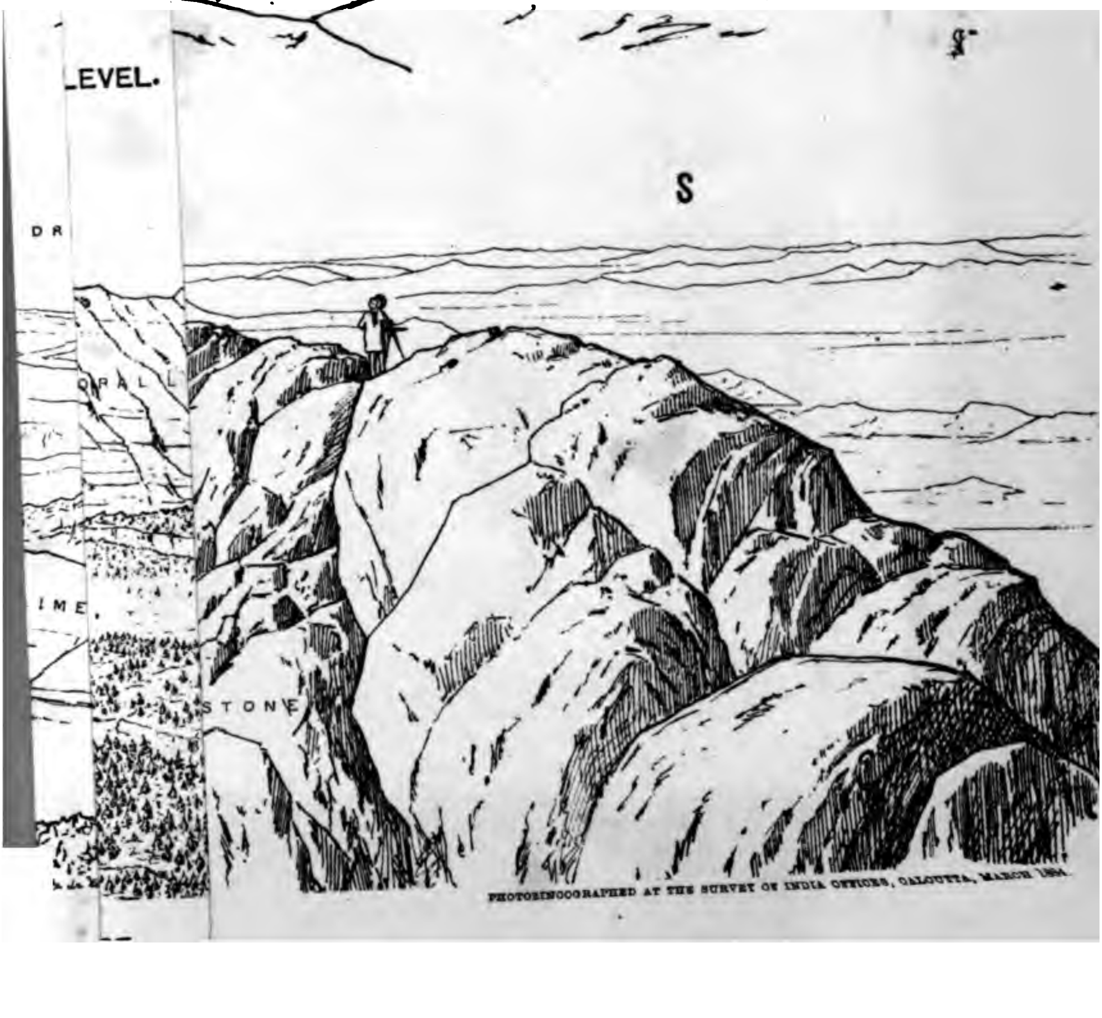
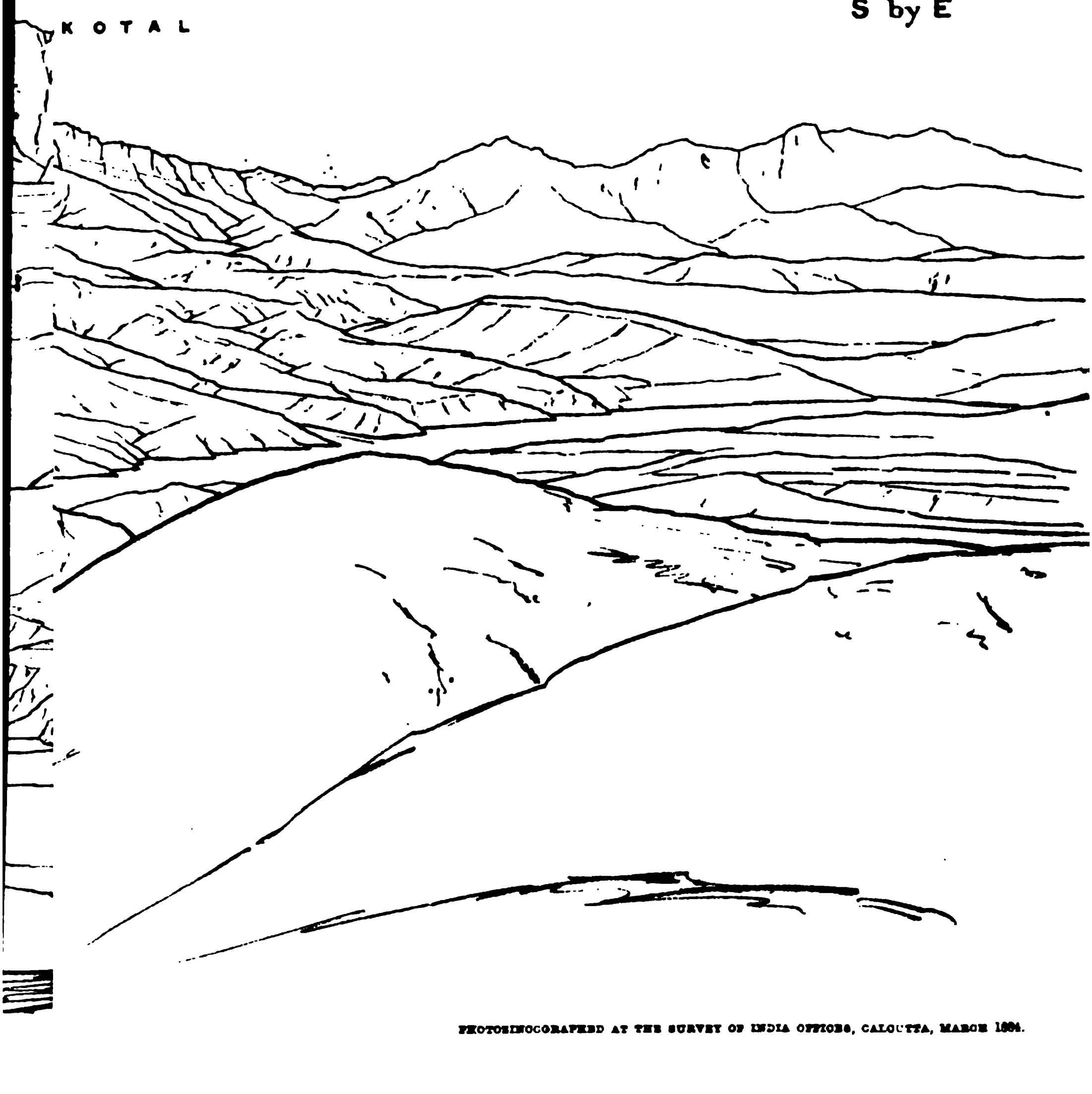
On the Travancore coast there are certain spots where, in the height of the south-west monsoon, and on a coast exposed to its full force, ships can always anchor in smooth water. These anchorages have long been known to mariners, and have at various times attracted attention. In 1881 they were visited by Dr. W. King, Deputy Superintendent of the Geological Survey of India, who



PHOTOZINCOGRAPHED AT THE SURVEY OF INDIA OFFICES, CALCUTTA, MARCH 1884.



PHOTOZINCOGRAPHED AT THE SURVEY OF INDIA OFFICES, CALCUTTA, MARCH 1884.

AKE

found that the mud which formed the sea-bottom was not only greasy to the touch, but on analysis proved to contain an appreciable quantity of oil to which he attributed the smoothness of the water; this opinion has, however, been criticised by a writer in the *Madras Mail* (9th April last), who gave a totally different explanation, which I shall try to explain as briefly as possible.

In the open sea the particles of water which form the waves move in approximately circular paths, each separate particle moving upwards, then forwards, and so round by a downward and backward motion to its original position; as long as the waves are in deep water they move forward as rollers, but the water itself does not move forward except so far as it is forced forwards by the wind in a manner I shall explain afterwards.

Now, if these waves come on to a shelving beach, the particles of water are not free to move backwards in the lower part of their course, but are restrained by friction on the beach, and the consequence is that those particles which are moving forwards in their course get ahead of the others, and the wave curls over and breaks. But a solid shore is not necessary to make the waves break, for suppose it to be replaced by some liquid, like treacle or tar whose particles have not nearly the same freedom of motion as water, the lower part of the waves would be held back in the same way as by a solid shore, but to a less extent; so that the wave could travel further without breaking, but must break at last.

The theory of the writer in the *Madras Mail* is this: We know that during the monsoon large quantities of fresh water are poured off the land into the sea, that on these mud banks fresh water may sometimes be taken in alongside, that in any case the water at the surface is much fresher than sea water, and being in consequence lighter, floats out to sea on top of the heavier sea water. Now, the difference between fresh water and salt is of the same in kind as that between water and treacle, though less in degree; the separate particles of salt water have not so great a freedom of motion as those of fresh water; and if, as is the case in these mud banks, the salt water is charged with fine mud, the difference is increased. Let us suppose, then, that outside the anchorage is a strip of sea where there is a shallow layer of comparatively fresh water lying upon muddy salt water. The great waves raised by the south-west monsoon roll into this, but immediately they reach it the bottom of the wave is held back on account of the less freedom of motion of the particles, or the greater viscosity of the salt water; and, if only this layer of fresh water is broad enough, they will break and be destroyed. In this way the absence of the larger waves from these anchorages might be explained. But there is another class of waves which, in comparison with the first, might be called ripples; these are not large enough to follow at anything like the same rate as the wind, for the larger a wave the faster it travels, and in consequence the crests are often blown over by the wind. It is to these that the small patches of foam are due which may be seen forming on the tops of the waves even in the open ocean, and which are often called "breakers" by landsmen, though their true nature is very different from that of the breakers formed on shore. I have not any definite information as to whether these may or may not be seen on the anchorages; if they are not, it is most probably due to the oil in the mud, which, however, would hardly account for

the absence of the larger waves raised by the monsoon acting on hundreds of miles of sea.

At present so little is known of the facts regarding these anchorages that no proper explanation can be given, and it is with a view to obtaining the necessary information that the following interrogatory is issued. When the answers are collected we should be in a position to give the true explanation of these very peculiar and very interesting patches of smooth water.

GENERAL.

1. What experience have you had of the Western coast?

2. Are you personally acquainted with the smooth-water anchorages of Alleppy and Narrakal; if so, about how often have you anchored there?

3. Do you know of any other similar places on the Western coast where smooth water can be found during the south-west monsoon? If so, what kind of bottom is found on them?

4. What is your experience near the mouths of rivers and other places where the surface of the sea is covered with fresh or brackish water during the monsoons? Do the waves in six fathoms of water and over generally run as large as in the open sea, or are they markedly smaller?

ALLEPPY AND NARRAKAL BANKS.

5. Have you ever, during the south-west monsoon, known the sea over these banks to be salt—not merely brackish, but as salt as outside them? If so, was the water smooth or rough?

6. Of what size are the waves ordinarily seen during the south-west monsoon on the anchorages at Alleppy and Narrakal, and do they show broken water on their crests to any extent?

7. Have you ever noticed a film of oil on the surface of the water at Alleppy or Narrakal?

Notes on Auriferous Sands *of the* Subansiri River;—Pondicherry Lignite;—*and* Phosphatic Rocks at Musuri, *by* WILL. KING, B.A., D.Sc., *Officiating Superintendent, Geological Survey of India.*

1.—Auriferous Sands *of the* Subansiri River.

It has been long known that gold is obtainable in a small way from the sands of the Assam rivers, but fresh hopes regarding their productiveness have been raised through some reported rich washings. On the 2nd June last the following telegraphic report was given in the *Englishman* of that date:—

"DIBRUGARH, MAY 30.

"Mr. Scott Campbell, who has the monopoly of gold washing in North Lakhimpur, has received from Messrs. King, Hamilton & Co. the results of an analysis of some specimens of average washings from the Subansiri sands. In 100 parts of washed sand decimal 161 of gold were found, being over twenty-six ounces per ton. Former rough tests by local goldsmiths gave about nine ounces per ton. Specimens of Subansiri washings have also been sent to London for analysis. The place whence washings were taken is well in British territory, below the Pithalibam

tea garden. Unless the analysts' figures, as given by Messrs. King, Hamilton & Co., are erroneous or the specimens unfair, the Subansiri sands must be the richest alluvial gold deposit known. Mr. Campbell guarantees the specimens analysed as average washings."

This is sufficiently startling in its suggestions of the richness of these sands; and a leading article on it, in the same paper, attracted the attention of the Government of India.

Subsequent correspondence made me acquainted with the analyst, who wrote that he had based his calculation on the Assay Table in Mitchell's Manual of Assaying, which table is made out on the proportion that if 200 grains of *ore* give fine metal at such and such a rate, then one ton of *ore* will yield so much. The proportion of ·161 grains of the telegraphic account had, however, been obtained in 100 grains of the material, and by an oversight, the rate of over 26 ounces to the ton was given instead of double that amount, or 52 oz. 11 dwts. 20 grs.

I have italicised the word "ore" in the last paragraph, because that word is used, in the Assay Table quoted, as a synonym for "mineral" or vein-stuff, and cannot for a moment be considered as applicable to *washed sand*. Indeed, if the term ore is to be used, then the ore in the present case is the Subansiri sand, not the washed part of it. It is this misuse of terms, and estimation on a particular filtering or sifting of a material known to contain gold dust, which invalidate the whole argument. All that has been elucidated by Mr. Campbell's find and the assay is that a minute quantity of washed sand gives a good percentage of gold; nothing is vouchsafed as to the amount of river sand which was treated for this residue, or of the time and labour consumed in that treatment.

It appears, from previous observations, to be a fairly well established fact that the Subansiri sands have generally given the best yields among the many rivers of the Lakhimpur district which itself is one of the most favoured of the auriferous regions in Assam. For instance, it is recorded that the average yield of the Subansiri river, about 1853, was from three to four pounds of gold for the year. There is little doubt that improved methods of running such sands through cradles should make the out-turn better than it ever has been under the crude manipulation of the native washer: but that this will ever come near the anticipations of Mr. Campbell is more than the indications of the rocks of the up-land country, or the history of gold washing in Assam will allow. At the very best, there may be spots in the great plain of the Brahmaputra which hold gold in some quantity, but the hitting off these is almost as chance a thing as can be conceived in so essentially precarious an occupation as gold prospecting.

There is, moreover, some very suggestive evidence, adducible from actual outturns of gold from washed sands in the Lakhimpur district, as ascertained by Colonels Dalton and Hannay in 1855.

"This gold was obtained partly in a Californian cradle washed by four men at Gurumora, 18 miles below Bhramakhund. Two and a half tons of stuff which were passed through it yielded 30 grains, or in value Rs. 2-8. In the native trough (or *duruni*), washed by three men, the yield from 18 cwt. of stuff washed in one day was about 12 grains, or in value 1 rupee. The natives looked upon this as a poor yield, stating that after a flood they sometimes got double that amount."[1]

It is hardly necessary to point out that this very practical mode of testing the

[1] Manual of the Geology of India, Part III, p. 225.

auriferousness of the sands is of infinitely more value than any estimate based on an examination of a sample of concentrated washings.

2.—Pondicherry Lignite.

During the last two years various reports have appeared at odd times regarding an extensive and thick deposit of lignite occurring between Pondicherry and Cuddalore, which is to be compressed into bricks or patent fuel, and so help to relieve Madras from the reproach of having no coal or other mineral form of fuel within its proper borders.

Mons. Poilay, the Engineer of the Company which proposes to utilize this resource, was the discoverer of the deposit; and it is from this gentleman that I have personally and by letter, always received the most obliging information concerning its occurrence.

Two thick beds of a dark brown or black deposit, some of which I would rather describe as a carbonaceous mud than a lignite, were struck during some of the artesian boring operations in the alluvial flat between Cuddalore and Pondicherry, though still in French territory. Subsequent borings were carried out at Bávur or Bahour (French), Koniakovil, and Aranganur, three villages at the corners of an acute triangular area having its longest side, of about 5 miles, between Bávur and Koniakovil.

The boring at Bávur pierced a bed of this carbonaceous deposit ("Lignite très noir avec pyrite de fer" of Mr. Poilay's section) nearly 35 feet thick, at a depth of 275½ feet. At Aranganur, nearly 2 miles north-north-east of Bávur, a similar deposit ("Lignite pur") over 27 feet thick was struck at 203 feet; and at 94 feet deeper another bed ("lignite") 5½ feet in thickness. This last would appear to correspond to a very thin streak at Bávur, some 30 feet below the thick seam at that place. At Koniakovil, a little more than 5 miles north-east by north of Bávur, a 50 feet bed of "Lignite noir compacte" was met with at 330 feet.

Other borings in the intermediate ground may have been made since the last bore sections (dated 20th October 1883) were supplied to me by my friend Mr. Poilay; but I have received no further information on this point. It is assumed that these three borings have struck the same thick bed, and that it may be fairly continuous over the triangular area at least, as a great bed among the alluvial deposits. If all this be true and if the deposit come up to the standard reported of it, then undoubtedly Mr. Poilay's estimate of several hundred millions of tons of fuel is not exaggerated.

Some assays of the material do not, however, bear favourable comparison with those which were in the first instance made for the explorers by French chemists. On the other hand, rather more promising but still unsatisfactory results have lately become public, through a report by the Officiating Chemical Examiner for the Bengal Government, to which reference will be made further on.

The original assays, given in a preliminary notice by Mr. Poilay, are sufficiently promising:—

"The assay of a sample of this lignite, based on a report drawn up by M. Philaire "Pharmacien de la Marine à Pondichery," dated 4th May 1882, gives by calcination, 6 per cent. of ash, 49 per cent. of volatile matter, and 45 per cent. of coke; dullish black blistered, unequal fracture, friable, without woody texture

"The elementary analysis gave the following result:—

Carbon	59·9
Hydrogen	5·78
Oxygen and Azote	28·32
	94·00

"The calorific power of this combustible, as determined by M. Philaire, is 4,182, with a density of 1·183."

Subsequent examination in Paris gave even better and presumably more reliable results: thus, seven samples gave a mean of 8·35 of ash and 91·65 of volatile matters and coke.

A comparison is then instituted between the Bávur deposit and the lignite of the Bouches de Rhone, in the following table:—

	Bávur.	Bouches de Rhone.
Density	1·183	1·254
Nature of Coke.	Intumesced.	Pulverulent.
Carbon	59·90	63·88
Hydrogen	5·78	4·58
Oxygen and Azote	28·32	18·11
Ash	6·00	13·43
	100·00	100·00
Hydrogen in excess	2·24	2·32
Calorific power	4182	5961

Our own trials of samples of this deposit gave very different resu'ts. Mr. Poilay very kindly intrusted several pounds weight of some to me, which he warned me was not as good as that of the proper thick bed, and which was from the lower thin streak. This was a nearly black, or brownish-black, crumbly, slightly sandy carbonaceous mud which soiled the fingers. I expressed my doubts as to the proper lignitic character of the material; but M. Poilay seemed to have every confidence in the sample he was thus confiding to my care. It was then submitted to my colleague, Mr. F. Mallet, in the Survey laboratory. Some 20 to 25 lbs. of the black mud were powdered and well mixed up, a sample of which gave the following composition:—

Moisture	22·00
Volatile matter (exclusive of water)	23·90
Fixed Carbon	21·60
Ash	32·50
	100·00

Does not cake, ash light buff.

A former analysis by Sub-Assistant Hira Lal gave—

Moisture	16·76
Volatile matter (exclusive of water)	26·66
Fixed Carbon	34·30
Ash	22·28
	100·00

Does not cake, ash reddish.

A couple of months later, Mr. Mallet wrote to me:—

"Mr. Daly, of the Bengal Pilot Service, lately brought up some more samples of the Pondicherry lignite, and some manufactured sub-cylindrical bricks. It is evident that the stuff varies very much in composition, as may be seen by comparing these analyses with those previously made."

	Lignite.	Brick.
Moisture	35·3	17·4
Volatile matter (exclusive of water)	29·1	25·6
Fixed Carbon	25·2	23·0
Ash	10·4	34·0
	100·0	100·0
	Does not cake, ash ochre yellow.	Does not cake, ash buff white.

This lignite is a black-brown hardened mud, with a few minute sandy particles scattered through it, carbonaceous.

The latest examination of the Bávur lignite is that made by Mr. Waddell, the Officiating Chemical Examiner for the Bengal Government;[1] and here again are some curious results, though they do come nearer the original assays put forward by M. Poilay:—

These specimens of lignite and patent fuel were submitted to Dr. Waddell by the Public Works Department, Government of Bengal, namely:—*Lignite in its normal condition; Lignite mixed with tar and allowed to dry in block;* and *Lignite macerated and mixed with water and allowed to dry in block.* The "lignite in its normal condition" is described as of a jet black colour with a somewhat vitreous fracture and devoid of ligneous structure. This is, of course, the form (normal condition) in which every one would first of all prefer examining the deposit; but I am bound to state that none of the material supplied to the Survey answers this description.

Our specimens answer rather to the macerated lignite sent to Dr. Waddell which "was of dark brown colour, dull fracture, thickly sewn with numerous white siliceous particles, dry to the feel, and readily crumbled under pressure:" except that they were not so sandy or full of siliceous particles.

So far, it seems very evident that a varied assortment of substances has been submitted for examination: thus, samples from the upper seam, specimens from the lower bed, and manufactured bricks of kinds, as well as a macerated article which it is difficult to comprehend.

[1] I first became aware of this report, by seeing it noticed in the *Madras Mail;* but my present information is from a copy supplied to me by the Revenue and Agricultural Department.

I will now take the liberty of reproducing Dr. Waddell's analyses, merely running his separate tables for calorific power and chemical composion into one :—

Samples.	No. 1. Lignite, macerated and mixed with water and allowed to dry in block.	No. 2. Lignite mixed with tar and allowed to dry in block.	No. 3. Lignite in its natural condition.
Calorific effect	5047	6382	5318
Water	9·750	9·145	16·276
Volatile Hydro-carbons	34·210	30·383	38·551
Coke: Carbon, fixed	23·090	29·402	37·720
Coke: Ash	32·950	31·067	7·451
TOTAL	100·000	99·997	99·998
Loss	......	·003	·002

On the face of it, these substances are sufficiently incongruous in their condition, in their calorific power, and in their amount of ash. It is not clear whether they have been procured from the same portion of the lignite bed: indeed it is more clear that they have not been so selected: and therefore they are hardly worth consideration as giving comparative values.

On the whole, sample No. 3, which has by all accounts remained free from treatment in any way, is the best fuel of the three; and I should not be at all surprised to find that it is a specimen from a band, or seam, or pocket, of more perfect lignite in the main thick bed. The calorific power of this sample (No. 3) is also comprehensible; but such is not the case with No. 2 which with less fixed carbon and 23 per cent. more of ash gives nearly 1,000 more units of heat. Another very remarkable feature about all these assays is this, that when once an artificial brick is made, the ash increases enormously.

In any case, samples (1) and (2) are very poor in spite of the calorific power attributed to them; and it is inconceivable how a locomotive or a steam-boat could be benefited by carrying about patent fuel containing 31 to 32 per cent. of ash.

The fact is, further and many assays and trials of average specimens of the lignite itself and the manufactured bricks must be made before any fair estimate can be arrived at of the capabilities of this deposit. As far as I can see, the problems to be solved in the development of this industry, as indicated by the experiments now extant, are how to get rid of an enormous amount of ash and moisture, and how to consolidate the bricks by a medium the price of which shall not handicap the working of the deposit.

3.—Phosphatic Beds, Musuri.

A very interesting discovery has been made at Musuri by the Rev. J. Parsons of Midlands, in which also Dr. H. Warth participated. Nodular bands have been long known as occurring in the black shales of Musuri, but while Mr. Parsons has been hammering among them for some years with the hope of finding fossils, and thus finding a more exact clue to the age of these rocks, he was struck by the marvellously bivalve-like appearance of some of the nodules. Indeed, the shape and even foraminal-like beak of some of them, give at first sight a remarkable semblance to certain terebratulidæ. There, however, the likeness ceases, and the true nodular structure of the sub-ellipsoidal bodies soon becomes evident.

It was next ascertained by Dr. Warth that these nodules and a thin seam of rock associated with them contained a sensible amount of phosphoric acid.

Mr. Parsons then sent several parcels of the nodules to the Survey for examination; and a later supply of them, together with fragments of the rocky seam (supposed to be phosphorite) were sent on to us by the Revenue and Agricultural Department as from Dr. Warth.

The nodules present none of the characters of coprolites; they are merely concretionary forms of a nearly black or dark-grey colour, generally rough on the surface, but occasionally smooth and rather soapy to the feel, and rather hard. They are only very slightly calcareous. Some of them are not even phosphatic or only very slightly so; indeed, they are extremely varied in their constitution according to the greater or lesser amount of their components or the absence of one or other of them. Taken in numbers, they are on the other hand essentially phosphatic, though not with lime phosphate.

A preliminary assay of one by Mr. Blyth, the Museum assistant, showed no trace of phosphorous: but further trials of a few gave as much as 4·89 per cent. of phosphoric acid.

The so-called *phosphorite* occurs in thin seams associated with the nodules. It is a nearly black, hard, somewhat vesicular (from the weathering out of ? sulphate of baryta) volcanic-looking rock, sprinkled through with small crystallisations of heavy spar. The colour, and the harsh somewhat scabrous look, give the volcanic aspect; but the rock is really only a non-nodular part of the shale band. It, too, has the varying constitution of the nodules; and may be called a phosphatic rock.

The specimens were next submitted to my colleague, Mr. E. J. Jones, who after a most careful series of experiments determined their composition as follows:—

"Results of analysis of portions of eight nodules.

Phosphate of Alumina.
" " Lime.
" " Magnesia.
Silicate of Alumina.
Sulphate of Baryta
Traces of Phosphate of Iron.
" " Sulphide of Copper.
Carbonaceous matter.
Silica.

Hydrofluoric Acid.
and small quantities of Iron, Magnesia and Lime, not as phosphates.

"Results of analysis of a rock supposed to be *phosphorite* :—

Phosphate of Alumina.
" " Lime.
" " Magnesia.
Silicate of Alumina.
Sulphate of Baryta.
Sulphide of Copper (traces).
Phosphate of Iron (traces).
Carbonaceous matter.
Silica

and traces of Lime, Magnesia, and Iron, not as phosphates.
Traces of carbonic and hydrofluoric acids.

Thus the qualitative composition is the same for both substances; but I have thought it best to give each, as the latter was examined some time after the first.

"Determination of phosphoric acid in the nodules :—

45·17 per cent. Phosphoric Acid.
or 35·84 " " Anhydride.

"Determination of phosphoric acid in the rock :—

41·8 per cent. Phosphoric Acid.
or 32·3 " " Anhydride.

"The most prevalent constituent in this form of shale is the phosphate of alumina.

A sample from five or six nodules, powdered, gives, according to Mr. Blyth, 8·42 per cent. of lime.

In all true phosphatic nodules, or phosphorite, the essential constituent is phosphate of lime, though the "strength and value of the minerals is calculated according to the amount of phosphoric acid there is in combination with the other minerals.[1]" There are only two cases recorded, namely the phosphatic deposits of Alta Vela, a small island near St. Domingo, and Redonda Island (16° 54′ N., 62° 21′ W.), which have little or no lime in their constitution. In ordinary phosphates, the lime runs as high as 56·62, or only as low as 32·62 per cent.: while the phosphoric acid varies between 20 and 40 per cent.

The Musuri phosphates might then be more properly distinguished as alumina phosphatic deposits. The treatment of such phosphate is more difficult and complicated than that of ordinary calcareous phosphate, but can be effected (according to Spence's process) by solution in sulphuric acid and addition of ammonia from gas-liquor. After the alumn has crystallized out the phosphoric acid in the mother liquor can be converted into artificial manure.

From a geological point of view, this discovery by Messrs. Parsons and Warth is particularly interesting as presenting indications of former life which may yet be more clearly displayed by the fossils themselves in the hitherto barren deposits of Musuri.

[1] See a very elaborate article on Phosphate of Lime, in "Earthy and other Minerals and Mining," by D. C. Davies, 1884, Chap. VII, Vol. X.

Mr. H. B. Foote's Work *at the* Billa Surgam Caves, *by* R. BRUCE FOOTE, F.G.S., *Deputy Superintendent, Geological Survey of India.*

Introductory.

Although the exploration of the Billa Surgam Caves was not very successful in its earlier stages, it has since then produced results of great interest, both archæologically and zoologically. The existence of prehistoric man in that quarter has been most conclusively proved, while much light has been thrown upon the former geographical distribution of some important genera and species of animals no longer existing wild in the south of India. The deeper the excavations have been carried both vertically and laterally into the recesses of the caves the more interesting and valuable have been the finds made.

A sketch of the first part of the exploratory work carried out by myself last year was given in the February number of the Records (Vol. XVII, Pt. I, 1884). At the beginning of the present year (1884), I was called off to other duties, but as His Excellency the Governor of Madras was anxious that the exploration work should not cease, it was entrusted to my son, Mr. Henry B. Foote, Lieutenant, Royal Artillery, who was temporarily attached to this Department, and took up the excavations where I had left off. My son had spent several weeks with me a few months before, and had afforded me great assistance in exploring and excavating different caves, and had therefore gained a knowledge of the country and of the people whom he had to employ in the further explorations. This he took up early in March, and carried it on till the end of May, during which time he cleared out the remaining half of the Charnel House Cave very nearly to the bottom of the narrow passage to which the cave contracts downward, a passage so narrow that the diggers have difficulty in finding room to work.

Mr. Henry Foote's work in the Charnel House Cave.

Mr. Henry Foote also commenced excavating the Purgatory Cave, and was thereby enabled to follow it fully 300 feet further into the hill. In a rough report of the work done by him, he says "I did not reach the end of this gallery as it was too narrow, but if it were cleared out, it would no doubt be possible to go much further in and also up several branches which were too much filled up to be entered."

In the Purgatory Cave.

When first explored, two pits were found in this long and narrow cave—one some 15—20 feet within its mouth, the other some 10 yards or so further in. Nothing certain could be ascertained from the Kotal villagers as to the origin of these pits, which rumour ascribed to treasure hunters, but they were very likely sunk by guano diggers; the soil in the cave being largely made up of dry dusty guano derived from the droppings of the clouds of bats which live in the dark part of the passages. On clearing the guano-soil out of the outer pit, Mr. Henry Foote found its "further wall composed of a stalagmitic mass," of which he says "I fancied it might form a floor, and so continued the pit down to a depth of about 13 feet, when I reached the bottom of the cave, and found that my surmise was correct, there being a space of about 3 to 4 feet under the stalagmite filled with a red clay, with pieces of stalagmite and limestone forming a sort of breccia. As

I had not much time at my disposal I could not then clear out the whole cave systematically, so I proceeded to clear out the earth under the stalagmite floor. The floor continued for 9 yards and then gave way to the interstratified earth and bats' dung, and at this point I stopped. Among the finds in this cave were several fine teeth and a few bones. I found also, just at the place I stopped at, two small drinking bowls of rough earthen-ware at a depth of 11 feet below the surface. They are not of modern shape, but have no very distinctive character."

"As we advanced into the cave, the bats' dung stratum got thinner and disappeared altogether after 200 feet. The cave earth is here a wet grey clay." "I fancy that the earth at the bottom (under the stalagmite) is of great age, and once filled the whole cave as in the recesses there are pieces of it adhering to the roof."

In the Cathedral Cave.

In the Cathedral Cave, Mr. Henry Foote commenced systematic excavation about a month before the end of his time. He reports "I could not at first work in it, owing to the numerous swarms of bees which occupied it, but after destroying their nests twice, they retired up the cliff to a safe height, and I commenced work in one corner of the cave, under an overhanging piece of the wall which, being the only place the sun does not reach in the afternoon, was the most suitable for human habitation."[1] "Having cleared away the bats' dung, which was about a yard thick, over a surface of about 50 square feet, I commenced to excavate the beautifully stratified cave earth in layers of one yard in thickness. The top layer was very full of bats' dung which gradually disappeared as I got lower, when the earth became a rather stiff red clay." "There were a good many fallen blocks in places, but not so many as in the Charnel House. There were also a good many masses of stalagmite, mostly on the edge of my excavation, all *in situ*, and as they were of large size the cave earth underneath them must be of considerable antiquity."

Stalactites and stalagmites.

The Cathedral Cave contains many more stalactites and stalagmites than any of the others, and a great part of its eastern end is filled with an enormous mass, composed of both forms of the deposit, to which the name of the "High Altar" was given from its great resemblance to the sanctuary in a Roman Catholic Cathedral. It is impossible to give any closer idea of this remarkable cave without illustrations, which it is hoped will be forthcoming to accompany the final report on the cave work.

Traces of prehistoric man.

Cut bones.

The existence of man at a low stage of civilization was ascertained beyond fear of contradiction by the discovery of a well-made bone gouge and of two pieces of stag-horn which have been cut with some sharp instrument, one indeed has been deeply cut into and shaped into a rude implement. These were found in the Charnel House Cave at a depth of 15 and 16 feet below the surface respectively. The Cathedral Cave also yielded an implement of bone trimmed by many cuts of a sharp instrument into a rude knife shape. Two or three bones also were found show-

[1] The open exposure to the rays of the afternoon sun of a cave in the latitude of Billa Surgam would render the place practically untenantable for several hours. The concentration of heat radiated from the high cliffs at the back and around the Cathedral Cave is something tremendous.

ing distinct traces of having been scraped with a hard and sharp implement, the marks being such as would be made by a sharp stone flake.

Number of bones found.

A fair number of teeth and bones of various large and medium sized animals was collected, as well as many thousands of those of very small animals, such as squirrels, rats, mice, shrews and bats, also of small birds, snakes, lizards, frogs and toads. Shells of some of the existing species of landshells were found numerously, particularly those of *Helix nicobarica*, *Nanina tranquebarica* and *Pleurostoma* (*nodifera ?*).

Difficulty about determining the bones.

But little could be done towards the specific determination of the bones found, even where the genus was easily recognizable, the osteological collections available in Madras being far too small. In the few cases in which specific determination was feasible, the bones were found to belong to living species.

List of animals found.

The annexed list gives, as far as possible at present, the generic and specific names of the animals whose remains were found in the Billa Surgam Caves:—

MAMMALIA.

Presbytis (*Semnopithecus*) *priamus ?*	*Equus*, sp.
Macacus ? sp.	*Sus indicus*.
Chiroptera, several.	*Rusa aristotelis*.
Sorex, sp.	*Axis maculatus*.
Felis tigris.	*Memimna*.
„ sp.	*Antilope bezoartica ?*
Viverra zibetha ?	*Portax pictus*.
Herpestes griseus ?	*Capra ?*
Canis, sp.	*Ovis ?*
Sciurus, 2 or 3 sp.	*Bos*, sp.
Mus, 2 or 3 sp.	*Gavæus ?*
Hystrix leucurus ?	
Lepus, sp.	
Rhinoceros, sp. (? *javanicus*).	

AVES.

Several genera belonging to the orders Raptores and Grallatores (?)

REPTILIA.

Crocodilus.	*Agama*, sp.
Varanus dracæna.	*Lacerta*, sp.

AMPHIBIA.

Rana.
Bufo.

Condition of the bones.

The remains found all occurred as detached teeth and bones or portions of bones. The best specimens are a few rami of mandibles and two or three maxillæ retaining four or five teeth a piece. Most of the specimens, however fragmentary, are well preserved for

individual determination. Feww ere thickly encrusted with kankar, few also were found in a state of great brittleness, but few also are highly mineralized. The number of species already recognized is very large in proportion to the number of bones of the larger animals which were found, but it may be expected to be increased very considerably when the large series of small bones collected shall have been fully examined.

Source whence the small bones were derived.

The extremely great number of bones of small rodents, birds, reptiles, &c., &c., which were found in the different beds of the cave earth, may be reasonably attributed in great part to a cause which is still in action in these caves and adjoining ones. The cause in question is the frequent visits of large birds of prey, such as eagles, kites, hawks, and owls who seek the quiet and retirement of the caves in order to get rid of the undigested hard parts of their prey, in the form of castings. Considerable accumulations of such castings were found in the Charnel House and Cathedral Caves as well as in several of the smaller ones. Osseous deposits of such character have doubtless often been covered up by the sediments brought into the caves by floods during wet seasons; the feathery and tendinous parts of the castings have decayed and only the bones remained behind.

No signs of continuous residence of man or predatory animals.

The evidence obtained so far goes to prove that the caves were not continuously inhabited either by man or predatory animals. The greatest number of bones found in the Charnel House Cave, for example, occurred in, or close to, the mouth of the small tunnel-like gallery opening into the cave at its upper extremity. These bones seem all to have been washed in from above by the stream which flowed out of this gallery in wet seasons, and which formed the several beds found in the upper end of the cave. The beds which occur at the mouth of the cave and which were formed by the main stream flowing through the several cañons, are remarkable for their poverty in fossil remains. How the bones entombed in the Cathedral Cave and in Purgatory reached their places of rest it would be premature to say till the excavations have proceeded considerably further.

There are no accumulations of Album græcum in any of the caves, such as would inevitably have been formed had they ever been long occupied by carnivorous animals, nor are there any considerable deposits of ashes and charcoal with fragments of bones and other indications of man's continued residence which formed such interesting accumulations in many other bone-caves.

No stone implements found.

No stone implements of any kind have been discovered in connection with the Billa Surgam Caves, excepting perhaps a minute triangular splinter of rock crystal which might have served as a drill.

Bitten and broken bones.

Of the broken bones which occurred in considerable numbers some bear distinct tooth marks, others, and more especially fragments of the thick and massive bones of large animals, appear broken with great violence, as if with a hammer or heavy stone, not splintered, as if bitten.

The great majority of bones whether unbroken or broken before being buried, as a very large number evidently were, retain their form distinctly and

show no signs of having been rolled far, which agrees with the inference that they were washed into the cave from only a very short distance.

Of the crushed and broken bones which were found in all the three caves explored, many had been reduced to that condition by the falling of heavy masses of limestone from the roof. No burnt bones were noticed in any of the caves.

Occurrence of the genera Equus and Rhinoceros.

A very interesting fact and one adding materially to our knowledge of the geographical distribution of the perissodactyle ungulata of India within the human period is the occurrence so far south in the Peninsula of the genus Equus and of a second species of Rhinoceros. The living Indian representative of the first named genus is *Equus onager*, the wild ass of Kutch, which occurs also in Gujerat and the countries west of the great Indian desert, but is quite unknown in the peninsula. Of the two Indian species of Rhinoceros now living, *Rh. indicus* is reported by Lydekker[1] to have been procured from "the turbary of Madras." The remains of rhinoceros found by Mr. Henry Foote belong to a smaller species with a very different dentition, being very markedly brachydont.

The Billa Surgam Rhinoceros.

The remains of rhinoceros found in the Charnel House Cave at Billa Surgam consist of a right upper molar (probably $\underline{\text{m. 1.}}$), a right lower molar (probably $\overline{\text{m. 1.}}$), and of a fragment of a right upper molar (probably $\underline{\text{m. 3.}}$). Of the first only the crown remains, but is in good condition. The lower molar retains the greater part of the fangs, and the crown is in good condition (one little chip out of the anterior part excepted). The two were not found together, and the lower molar may probably have belonged to a larger individual than the upper The fragment of the upper molar ($\underline{\text{m. 3.}}$) must have belonged to a very much smaller individual than either of the others. It shows but small signs of wear and could only have been cut a very short time before the death of its possessor. The other two teeth are greatly worn and must have belonged to fully adult or old individuals.

The upper molar is very characteristic in shape, and quite unlike any of the fossil Asiatic rhinoceroses already described. It is also quite unlike the molars of *Rhinoceros indicus*, but bears considerable resemblance to the molar of *Rh. sondaicus* (*javanicus*) figured by Owen in plate 138 of his Odontography.

The Billa Surgam horse.

The remains of Equus found were the following:—

1. A molar (lower, left)	Charnel House Cave.	
2. A metatarsal right	Cathedral Cave.	
3. A rudimentary metatarsal (Met. IV)[2]	do.	do.
4. A metatarsal (?) distal end	do.	do.
5. Three incisors, germs (upper ?)	do.	do.

Of these, numbers 1, 2, 3, and 5 belong to a small individual, of about the size of an ordinary ass. No. 4 belongs to a much larger, coarser built, animal.

[1] Lydekker, R. Synopsis of the fossil Vertebrata of India, Records, Geological Survey of India, Vol. XVI, p. 80, 1884.

[2] This rudimentary (left) metatarsal belongs doubtless to No. 2, as though found several feet apart in the cave earth (in squares Nos. 41Ca and 45Ca respectively) the two bones fit perfectly and show identical colour and degree of fossilization.

The section of the cave earth in the Charnel House Cave which was obtained by Mr. Henry Foote while excavating the northern half was much clearer and more instructive than that seen by me in the southern half; the former is therefore given below :—

Section of the Cave Earth, Charnel House Cave.

4′	A[1].	Surface (bats' dung) bed	3′
2′ 9″	A.	Rubble bed with large fallen blocks of limestone	2′ 9″
3′ 6″	B. C.	Stiff red clay, with sandy partings[1]	4′
2′ 6″	D. E.	Rubble bed	1′ 6″
3″ 9″	H.	Red cave earth, stony above	6″ 6″
1′ 3″	I.	Red and mottled cave earth	1′
	J.	Red-brown cave earth with patches of calcareous sand	1′
	K. L.	Red sandy cave earth with blocks of limestone	1′ 6″ 1′
	M. N. O. P.	Stiff marly clay taken out in four layers of 1 yard each in thickness	12′
			28′ 9″

The section is across the cave, rather to the westward of the centre, and runs in a nearly north-south line. The depth and nature of the deposits below P. are still unknown.

"The stratification of the cave earth, though very distinct in places, was more often obscure, and the large amount of infiltrated colouring matters (though often giving rise to very beautiful tints) were a source of great difficulty in the separation of one bed from that underneath it."

Contents of surface bed.

The artificial contents of the surface bed were, as already stated,[2] a few bits of broken pottery and charcoal, and a couple of small chank shells, doubtless once the property of some gossain or fakir. In addition to these were patches of small bones, &c., which are the half-weathered castings of large birds of prey before referred to (page 203). A full collection of these was made for comparison with the numerous bones of small animals which Newbold described as occurring in the cave earth below.

Human bones and teeth below the surface bed.

The loose red loam underlying the surface bed contained at one place (21 feet west of the entrance to the narrow passage at the east extremity of the cave), a number of human teeth and bones, belonging apparently to one and the same individual. The bones consisted of numerous fragments of a very thick calvarium (too broken to piece together successfully), fragments of the mandible and one or two vertebræ, ribs and parts of various limb bones.[3] They had been much broken up by a large mass of limestone which had fallen on the spot where they were buried, and being very brittle suffered a good deal more while being dug out.

[1] The Rubble bed "A" occupied only the front or western half of the cave; in the back or eastern half, "B" lays immediately under the surface bed "A[1]."

[2] Rough notes on Billa Surgam and other caves in Kurnool District, &c. Rec. G. S. of I., Vol. XVII, pt 1, page 27, 1884.

[3] These have not been compared as yet.

Finds in bed A.

The most interesting facts connected with the underlying strata in the Charnel House may be briefly enumerated at this place. Bed "A" yielded *inter alia* the right ramus of the mandible of a very young small ruminant (? *Antilope*), also the right maxilla with teeth of large monkey, differing slightly from *Presbytis* (*Semnopithecus*) *priamus*. From the relatively small size of the canine the owner was probably a female, but her jaws exceeded considerably in size that of a very fine male langur whose skull is in my collection.

In bed $\frac{B}{C}$.

In Bed $\frac{B}{C}$, Mr. Henry Foote found some charcoal and fragments of coarse unglazed pottery, as well as fragments of thin glazed red pottery of a very antique type.

Bed $\frac{D}{E}$ showed nothing of interest, and beds F and G, which lie further back in the cave and do not come within the section above given, were also devoid of anything of special interest.

In bed H.

In bed H, there was at one spot an immense quantity of small bones of rats, bats, lizards, &c., &c., accumulated either by an eddy in the small stream, which flowed through the eastern passage, or else representing one of the great collections of birds' castings above referred to.

Bone gouge in bed K.

In bed K, Mr. Henry Foote found the bone gouge above referred to "the best specimen of man's work that was found in the caves." "The hollow of the gouge is highly polished probably by use." "The cutting edge is gone, but the other edges show distinct marks of having been cut with a sharp instrument. It was found on the north side of the cave, about 4 yards from the mouth of the small passage, at a total depth of 15 feet below the surface."

Cut stag-horns in bed L.

Of bed L, Mr. Henry Foote says "it contained a little charcoal at the mouth of the small passage, this being the lowest horizon at which I found traces of man, the depth being 16 feet 6 inches. Associated with the charcoal, I found two pieces of stag-horns, which present distinctly cut surfaces." The one, as already pointed out, is cut into something little a rude knife about 5 inches long, or it might possibly have been used as a small spear head if the but-end had been fixed vertically at the end of a pole. The other piece, which is 6¾ inches long and much thicker and heavier, has the further end distinctly cut on two sides, so that it forms a short but thick wedge. The whole piece looking like a rather rude pick-hammer. The cuttings are very clear and distinct on both implements. Bed L was the most prolific in large bones of any in the Charnel House. Among those found, it may be well to specialize a few of the most important.

1. The left ramus of the mandible of *Portax pictus*, fragment with 4 teeth (No. 7, 70 L).
2. Molar 3 (lower) of *P. pictus* (No. 9).
3. Five incisors (lower) of *P. pictus* (No. 12).
4. Carnassial (lower) left of *Viverra zibetha* ? (No. 16).
5. Lower left incisor $\frac{}{2}$ of *Antilope bezoartica*.
6. Cervical vertebra of *Portax pictus* ? (No. 56).

7. Olecranon (broken) of *Axis maculatus* ? (No. 57).
8. Left scapula of *A. maculatus* ? (No. 64).
9. Right scapula of *Rusa aristotelis* (No. 68).
10. Left tibia of *Axis maculatus* ? (No. 32).
11. Right tibia (distal end) of *A. maculatus* ? (No. 37).
12. Left calcaneum of ditto (No. 31).
13. Right femur of ditto (No. 33).
14. Metacarpal of ditto (No. 43).
15. Right tibia (distal end) of *Rusa aristotelis* ? (No. 36).
16. Left astragalus of ditto ? (No. 30).
17. Phalanx of *Capra* ? (No. 1.)

In bed M bones of monkey.

Bed M was also productive of bones and, in a recess in the side of the small passage at its bend, some remains of a large monkey were found consisting of a right maxilla with 3 molars and 2 premolars, the right ramus of the mandible with 3 molars and 1 premolar, also a fragment of a left ramus with the canine and 1 premolar, and lastly a lower left molar ($\overline{M. 2}$). All apparently belonged to the same individual.

The other important bones found in bed M were—

1. Os innominatum (right) of *Rusa*.
2. Ditto (do.) of *Axis*.
3. Femur (right) of *Antilope*.
4. Metatarsal (right) of *Axis* ?
5. Vertebra of a snake.

Beds in the passage.

The excavation of the beds in the inner-most part of the small passage was carried out by Mr. Henry Foote separately, as he found it impossible to make out their exact relation to the several beds of the cave earth in the outer cave. The cave earth beneath the surface (bats' dung) layer was red and so nearly homogeneous in character, owing to the absence of infiltrations of colour, that the division into layers for excavations must be considered a purely arbitrary one. The four divisions in which it was taken out were termed X, Y, Z, and X^1; of which Y yielded a small crocodile's tooth much blackened in colour, and X^1 the rather broken crown of a very large left lower premolar of some ruminant which was most likely that of a bison (Gavæus).

Finds in Purgatory Cave.

The most interesting bones Mr. Henry Foote obtained from the Purgatory Cave were as follows :—

1. The right upper carnassial tooth of a feline animal smaller than a tiger.
2. The right metatarsal bone of a large tiger (*Felis tigris*) of which the proximal end and the under side are wanting but the bone otherwise in good condition.
3. The right tibia of a large tiger, the proximal end wanting.

4 & 5. Two phalanges (right) of pes of *Felis tigris*. Besides these were seven or eight molars of different ruminants, large and small, which could not be satisfactorily determined.

Finds in the Cathedral Cave.

In the case of the Cathedral Cave the most important finds made by Mr. Henry Foote beside the Rhinoceros teeth and the teeth and bones of Equus above referred to (page 204) were—

1. A series of bones of *Hystrix* (*leucurus*), consisting of two mandibles and sundry molars and incisors belonging to several individuals.[1]
2. Two upper molars, four lower incisors, and two lower canines of *sus indicus*.
3. A series of bones of *Varanus*, including 3 maxillæ and 3 left rami of mandible and many vertebræ.
4. A series of bones of birds of several genera.

Conclusions as to the age of the caves.

The determination of the animal remains found in the Billa Surgam Caves, so far as has been practicable, shows that the very great majority, if not all the larger animals, belonged to living species; they must therefore be regarded as of pre-historic or post-pleistocene age. This result is in accordance with the evidence furnished by the bone implements found in the caves, which implements bear a very close resemblance to finds made in various pre-historic bone-caves in Europe. The stone implements, accompanying the European bone implements, belong to the neolithic, or polished, type; we may therefore very reasonably expect that, should stone implements be discovered during the further explorations, they will prove to be of the neolithic type. But we may also very reasonably anticipate that in some of the caves only partially explored at present, or in some of those still untouched, future explorations may bring to light remains of palæolithic man and pleistocene animals; for it must be borne in mind that palæolithic man lived in that region and left numerous implements behind him in the adjacent alluvium of the Khunder valley.

The results now communicated may, I believe, be accepted unhesitatingly, as very great care was taken both by my son and myself to register exactly the positions in which the bones were found.

I re-visited the caves in the beginning of May to see how the exploration was progressing, and was much gratified to find that Mr. Henry Foote had organized his band of excavators very thoroughly, so that the work proceeded steadily and safely.

The efficient way in which he carried out the very arduous piece of work confided to him fully justified the confidence with which I had recommended him to His Excellency Mr. Grant Duff, and will I trust be recognized by the authorities.

In conclusion, I must mention that our work at the caves was rendered much less irksome by the great interest taken in it by His Excellency Mr. Grant Duff. Our thanks are also due to Mr. W. H. Glenny, the Collector of Kurnool, for the kindly interest he took in the work throughout which greatly helped to make things easy in the matter of securing supplies and labour in a very outlandish place. Nor do we forget various acts of courtesy and kindness from the Nawab Sahib of Banaganpalli.

[1] Up to the time of the excavation porcupines were constantly trying to colonise the caves, and were only repressed by the use of traps built by the villagers of pieces of limestone. As it was, a couple of them was caught and killed by the diggers in one of the pits in Purgatory Cave

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Specimens of garnets (Spessartite ?) and of the mica schist in which they occur, from Kulu.

PRESENTED BY COL. G. GORDON YOUNG, COMMISSIONER, DHARMSALA, PUNJAB.

A large piece of Pumice, picked up at Sea, Lat. 80°S., Lon. 83°E., on 30th November 1883.

PRESENTED BY CAPT. HENRY MAYO.

A specimen of stibnite (antimony glance), and a button of metallic antimony reduced from cervantite, an ore of antimony, ($SbO_2 = Sb_2O_3 + Sb_2O_5$), from Maulmain, Burma.

PRESENTED BY W. R. CRIPER, ESQ.

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